ALMOND QUALITY PRESERVATION AND SHELF LIFE

How do storage conditions affect almond shelf life potential?

What is the projected shelf life of almonds under different storage and packaging conditions?

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

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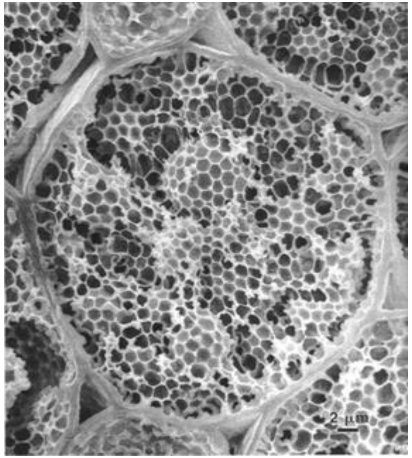
Unique physical and chemical properties provide great shelf-life potential for almonds



Scanning electron microscopy image of (unroasted) almond cell structure

Almonds are low-moisture (typically <5% moisture), high-oil-containing nuts with a long shelf life when properly handled.

- Almonds dried or processed to a moisture content of **less than 6%** undergo minimal biological (bacteria and mold growth) and chemical (browning) activities.
- Almonds have a good fatty acid profile: low in saturated and high in unsaturated fatty acids (S:M:P = 8:66:26). Oleic acid is dominant fatty acid (monounsaturated: M) and is less prone to oxidation than linoleic acid (polyunsaturated: P).
- Almond kernels have a honeycomb-like cellular structure, and oil droplets are held within subcellular cavities, which protects the oil from oxidation.

Both the high level of vitamin E in kernel flesh and the flavonoids in kernel skins provide additional protection against oxidation of almond oil.

Source: Perren and Escher (2013), Impact of roasting on nut quality, p. 173-197, Woodhead Publishing Ltd.

Almond properties, storage temperature and humidity, and packaging affect shelf-life potential

Almond quality and shelf life can be influenced by three general factors: the **product characteristics**, the **environment** during distribution and storage, and the **package**. Because these factors interact in many ways, shelf-life guidance for almonds should specify the product, storage conditions, and packaging.

Product Characteristics

- Composition: unsaturated fat and vitamin E levels, moisture/ water activity, initial quality
- Forms: natural/blanched, whole/cut, raw/roasted
- Roasted: dry/oil, roast level

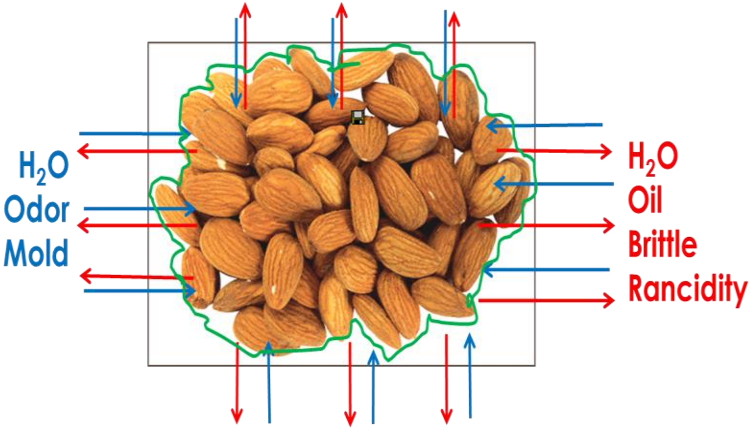
Environment

- Temperature
- Humidity
- Oxygen
- Processing conditions
- Insects, pests, microorganisms

Package

- Physical protection (film thickness)
- Moisture barrier (water vapor transmission rate)
- Oxygen barrier (gas transmission rate)
- Nitrogen-flush or vacuum packing

Almonds can react to environmental conditions during storage and transportation



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**.

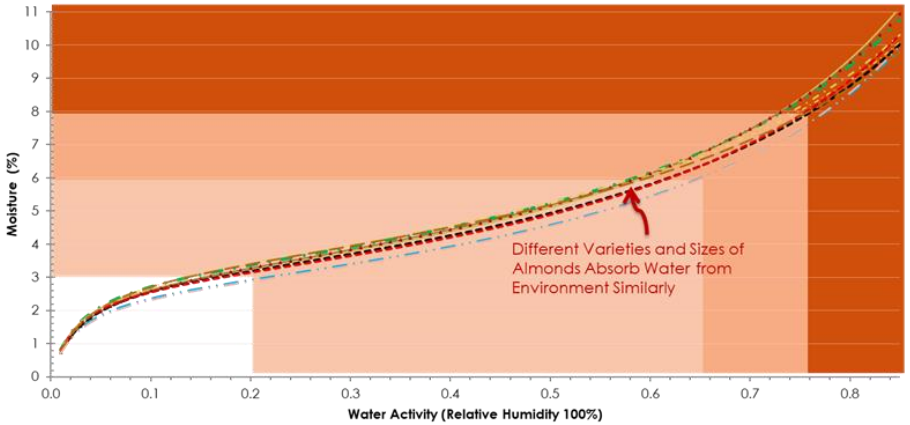
- Unwanted moisture migration in almonds may affect texture, microbial stability, and the rate of various chemical reactions that impact shelf life.
- When almonds pick up moisture (absorption), they may lose some of their crunch, mold may start to grow, and lipid oxidation increases. Moisture loss (desorption) may lead to some desirable changes, such as more crunch, but at very low moisture lipid, oxidation also increases.

Protecting almonds in packaging with good barrier properties limits the interactions between kernels, environmental humidity, and oxygen.

Changing humidity alters product moisture, leading to quality fluctuations

The effects of environmental humidity on almond moisture levels are expressed by **water sorption isotherms**.

Isotherms show that at a range from 20 to 65% RH, almonds will retain moisture levels of 3.0 to 6.0%; at these moisture levels, almonds are less prone to biological or chemical reactions.



- Moisture levels of 3.0 to 5.5% are more ideal for almonds – these levels can be achieved at 20 to 60% RH.
- It is critical to maintain a steady environmental RH so that moisture levels in almonds do not fluctuate during storage. Changes in almond moisture levels will impact texture and quality.

Sources: Labuza et al. (2010), unpublished data; see also https://www.almonds.com/almond-calculator/html/minnesota.html

Quality deterioration begins with increased moisture

At moisture >8% (RH >75%):

- Stimulates biological activities and texture changes; accelerates lipid oxidation, enzymatic activities, and non-enzymatic browning
- Mold growth may be visible in less than 3 weeks

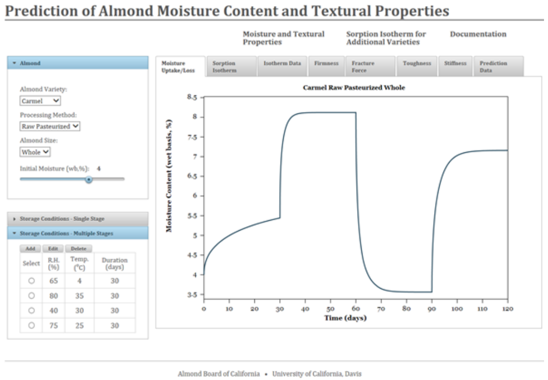
At moisture 6–8% (RH 65–75%):

- Texture deterioration; lipid oxidation; enzymatic and non-enzymatic browning occur but at a slower rate than at RH >75%
- Soggy texture is apparent; quality changes vary with temperature

Almond moisture levels increase at elevated humidity, leading to texture deterioration and release of free fatty acids that initiate oil oxidation, resulting in rancidity development. High temperatures accelerate textural and chemical changes.

- An online model is available to predict the effects of environmental RH on almond moisture content and the impact on texture

Almond (almonds.com)



Sources: Taitano et al. (2012), J. Food Proc. Eng. 35: 840-850; Taitano & Singh (2012), Int. J. Food Studies 1(1): 61-75; Lin et al. (2012), J. Food Sci. 77(6): 583-593.

What quality parameters are indicative for shelf life?

Texture deterioration due to elevated moisture content can be evaluated by measuring:

- Moisture
- Water activity
- Texture parameters

Rancidity development due to oil oxidation can be evaluated by measuring:

- Free fatty acids (FFA)
- Peroxide value (PV)
- Hexanal and other off-flavor volatiles

Shelf life determination relies on both analytical testing and sensory evaluation. No single chemical indicator or sensory attribute leads to sample rejection.

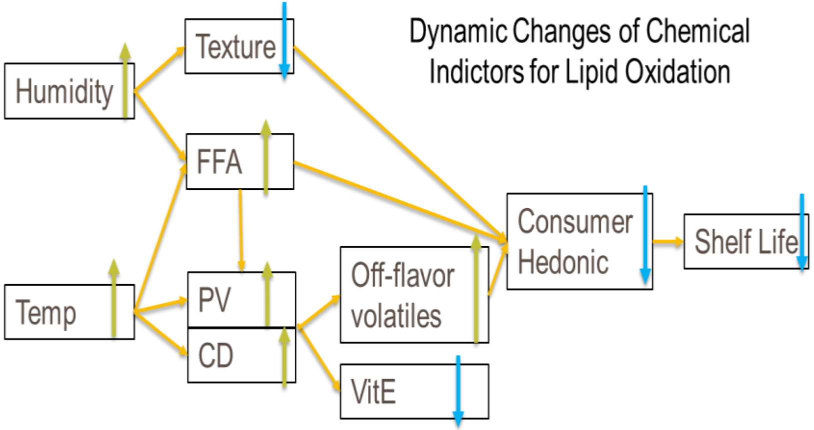
Analytical parameters commonly used in evaluating shelf life include moisture content, free fatty acids (FFA), and peroxide value (PV). Other volatile measurements such as hexanal may be useful.

- Note: FFA and PV values may fluctuate over storage time and conditions – lower levels don't always reflect good quality and may be due to later stages of oil oxidation when both free fatty acids and peroxides are further decomposed. So their values should be evaluated in conjunction with product storage history.

Kernel acceptability or rejection by consumers is complex, although texture deterioration and off-flavor rancid notes are two major factors critical to consumer rejection.

- For raw kernels, flavor is the greatest contributor to acceptability, followed by texture changes.
- For roasted kernels, rancidity development and texture changes are significant predictors of overall acceptability.

Rancidity is a major factor in consumer rejection of almonds



Lipid oxidation is a complex series of undesirable reactions that cause the breakdown of fats and oils. In oil-containing foods like almonds, oxidation reactions lead to a loss of quality as the nuts develop "**rancid**" flavors and odors.

- Oxidation can be measured by testing for the presence or accumulation of one or more of the primary and secondary breakdown products (e.g., peroxides, off-flavor volatiles).
- High storage temperatures, increased moisture, light and some metals (e.g., iron) may promote lipid oxidation in almonds and reduce shelf life.
- Processing also makes almonds more susceptible to oxidation; blanching and cutting increase the surface area exposed to oxygen, and roasting changes the almond microstructure, which allows more oil within the cells to be exposed to oxygen.

How do temperature, humidity and packaging impact shelf life?

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	Raw	Roasted
Unlined cardboard box (UC) (600 ± 5 g)	X	
Polypropylene bag (PPB) (300 ± 5 g) [a]	X	X
High-barrier bag (HBB) (300 ± 5 g)		X

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

UC: No WV or O_2 barrier

PPB: 100 µm (4 mil), WVTR = 8 g/m^2/day; OTR = 860 cm^3/m^2/day

HBB (PET/Al/PE: polyethylene terephthalate 100 µm/ aluminum 100 µm/ polyethylene 75 µm): WVTR <0.5 g/m^2/day; OTR <1 cm^3/m^2/day

A storage study conducted at University of Georgia explored the shelf life of raw and roasted Nonpareil almonds in different package types stored at various combinations of temperature and humidity.

- Almonds were assessed by analytical testing and sensory evaluation.

Temp: 4, 15, 25, 35°C
RH: 50 & 65%

Sources: Cheely et al. (2018), LWT-Food Sci. Tech. 91: 498-504; Pleasance et al. (2018), J. Food Sci 83: 822-830; Parrish et al. (2019), Int. J. Food Sci. & Technol. 54(6): 2190-2198.

Reducing temperature and humidity extends shelf life

A mathematical model[a] developed from the storage study at the University of Georgia uses temperature and relative humidity to predict approximately how long almonds will maintain sufficient sensory quality:

Months until sensory failure = 49 − .59(°C) − .42(RH%)

- This model assumes raw almonds and storage in unlined cardboard but still provides a useful general guideline.
- For example, under minimum storage guidelines (**10°C/65% RH**; see inset), the model estimates shelf life of raw almonds to be **15.8 months**.
- Under storage at lower humidity (e.g.,10°C/**55% RH**), shelf life is estimated to be **20 months**, an increase of ~4.2 months.

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[a] Model assumes storage conditions within the range of study assessment (4°C/50% RH to 35°C/65% RH). Sensory failure = rejection by 25% or more panelists.

Sources: Cheely et al. (2018), LWT-Food Sci. Tech. 91: 498-504; Pleasance et al. (2018), J. Food Sci 83: 822-830; Parrish et al. (2019), Int. J. Food Sci. & Technol. 54(6): 2190-2198.

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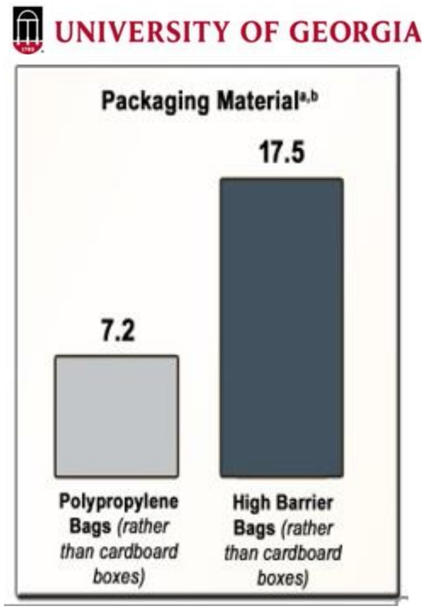
Packaging extends shelf life



Sensory failure = Rejection by 25% or more panelists

According to both sensory and chemical assessments, the choice of packaging material had dramatic effects on almond stability:

- Relative to storage in unlined cardboard cartons, **polypropylene bags** (N_2-flushed; 100 µm thickness; WVTR = 8 $g/m^2/d$) were shown to improve expected shelf life by **~7.2 months**
- **High-barrier bags** (N_2-flushed; 100 µm PET/100 µm Al/75 µm PE; WVTR <0.5 $g/m^2/d$) were shown to improve expected shelf life by **~15–20 months**.

[a] Numeric comparisons of packaging materials are presented as deductions according to findings that span multiple data sets, conditions, principles of analysis, and publications. These should be treated as approximate guidelines. If interested in more detailed quantifications, readers are encouraged to refer to cited sources.

[b] Comparison between unlined cardboard boxes and high-barrier bags is an extrapolation according to a stepwise comparison of unlined cardboard vs. polypropylene bags and polypropylene bags vs. high-barrier bags.

Sources: Cheely et al. (2018), LWT-Food Sci. Tech. 91: 498-504; Pleasance et al. (2018), J. Food Sci 83: 822-830; Parrish et al. (2019), Int. J. Food Sci. & Technol. 54(6): 2190-2198.

Storage Recommendations

Traditional Recommendations:

- Store under cool and dry conditions (<10°C/50°F and <65% relative humidity)
- Maintain almond moisture at 6% or less
- Avoid exposure to strong odors, as almonds can absorb odors of other materials if exposed for prolonged periods

New Recommendations:

- Store under cool and dry conditions (<15°C/59°F and <60% relative humidity)
- Maintain almond moisture at 3 to 5.5% for optimal stability
- Use packages with good barrier properties against water and air transmission, and prevent infestation, to maximize shelf life when affordable and feasible
- Avoid exposure to light and adjacent materials with extraneous odors

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