Almond Shelf Life Factors

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1. Introduction

Almonds are considered to be a relatively low-moisture, high-oil-containing nut with a long shelf life when properly handled. The shelf life is controlled 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 impact shelf life. Because of these interactions, shelf life guidance for almonds must specify the product and the storage conditions.

Major factors influencing almond quality and shelf life

Product characteristics	Environment	Package
Composition: moisture content, unsaturated fats Water activity Form: inshell, raw/natural, blanched, cut, roasted Cut products: size of pieces Roasted products: dry or oil roast, roast level	Temperature Humidity Oxygen Processing conditions Insects, pests, microorganisms	Physical protection Moisture barrier Gas barrier: oxygen, odors

2. What Causes Quality Changes In Almonds?

Controlling moisture, temperature, and oxygen is essential to preserve almond quality and shelf stability. Shelled and inshell almonds are naturally low in moisture (~3–6% water)—this low moisture content helps to minimize chemical and enzymatic reactions in the nuts. Almond moisture should be maintained at 6% or less. Storage temperature affects moisture pickup and loss and the rate at which almonds react with oxygen. Almonds contain about 50% fat (oil)—this fat is composed mainly of unsaturated fatty acids that can react with oxygen and could cause quality problems during storage, particularly in processed almond forms. Almonds are rich in vitamin E (alpha-tocopherol)—this natural antioxidant helps protect the fat from reacting with oxygen when almonds are stored under cool, dry conditions.

Almonds can have a long shelf life (up to 2 years), but as a natural ingredient they don't last forever. At the end of their shelf life almonds become unacceptable often due to major changes in flavor, texture, and/or appearance. The reactions causing these undesirable changes can be very complex. The following provides examples and environmental factors that impacts quality and ultimately shelf life.

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2.1 Moisture migration

Almonds can pick up or lose moisture depending on their initial moisture content and the humidity of the surrounding environment—this is called moisture migration—and storage temperature can play a critical role. 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 like 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 migration requires either a moisture-barrier package and/or reducing the humidity of the environment.

Storage for all almond forms at cool and dry conditions (<10°C/50°F and <65% relative humidity) is recommended. The optimal goal of the recommended storage conditions is to maintain <6% moisture content, which helps preserve shelf life. A cool temperature of <10°C/50°F 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 2 years of shelf life when stored at the recommended conditions.

2.2 Lipid oxidation (Autoxidation)

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

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.

Water activity (a_w) level affects lipid oxidation rates—lipid oxidation is typically lowest when almond a_w is ~0.25 to 0.35 (~3–4% moisture content), and increases above or below that a_w range.

2.3 Rancidity development

Rancidity is a general term for the unacceptable off-flavors and off-odors that eventually develop as fats break down through various reactions and secondary products, such as volatile aldehydes, are formed. *Oxidative* rancidity occurs when fats react with oxygen (lipid oxidation or autoxidation). *Hydrolytic* rancidity occurs when free fatty acids are released from fats by the action of naturally occurring food enzymes in the presence of moisture (lipid hydrolysis).

2.4 Roasting & microstructure changes

Roasted almonds have a shorter shelf life than raw or blanched almonds. Roasting causes changes to the cell microstructure that can accelerate lipid oxidation and rancidity. In raw almonds the cell microstructure and the antioxidants naturally present protect the oil from oxygen in the environment. Within each cell are many small globular structures, called oleosomes, which contain the oil. A membrane network separates the oleosomes from each other and forms a honeycomb-like microstructure.

During roasting, the oleosomes burst as the membrane network is damaged, and extracellular space increases. Because of these microstructure changes, oil within the cells is more exposed to oxygen. Lipid oxidation reactions can start immediately after roasting, so almonds should be cooled immediately and protected from oxygen with suitable barrier packaging.

2.5 Brown discoloration

Raw and blanched almonds turn brown when stored at high temperatures (>38°C/100°F), especially at high humidity. For low-moisture foods like almonds the rate of browning increases with increased moisture (to a maximum at a water activity (a_w) level of ~0.7–0.75 (~6–8% moisture). The complex chemical reaction involved is known as non-enzymatic browning (or the Maillard reaction) and consists of several stages, with the eventual formation of compounds that have a brown appearance.

3. How Is Almond Quality Measured for Shelf Life Evaluation?

Some of the most common measurements used in assessing quality are described briefly below.

- Moisture
- Lipid oxidation & rancidity
- Sensory evaluation – often along with laboratory tests for lipid oxidation/rancidity and texture
- Microbiological counts

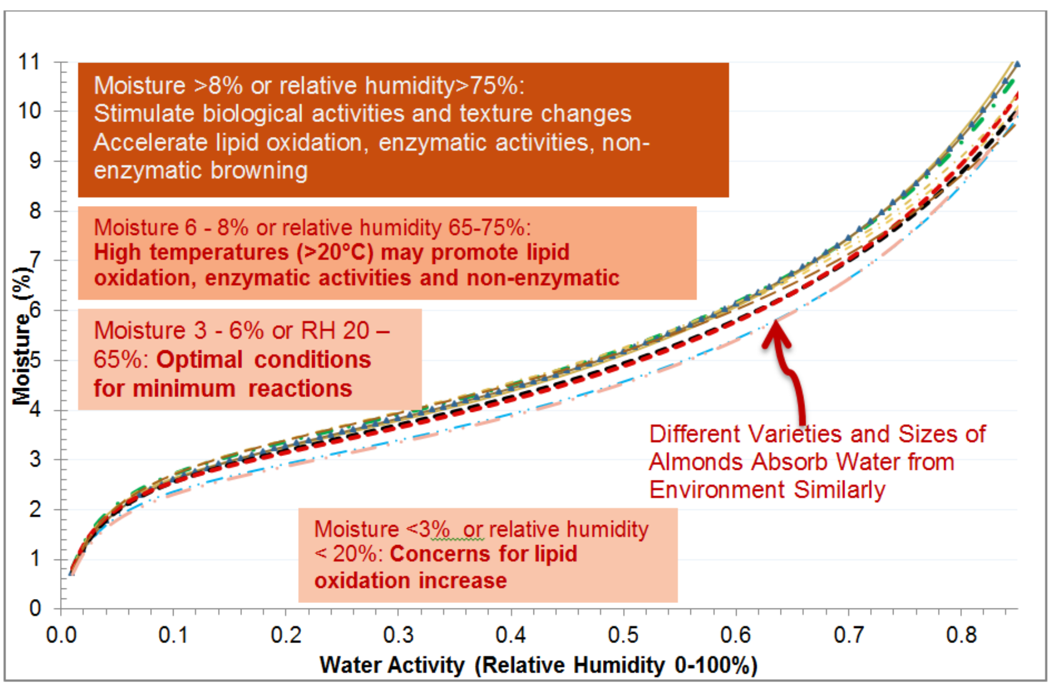
3.1 Moisture

Moisture content: the moisture content is a measure of the total water in a product.

- Moisture is expressed as % (percent) or g/100 g (g water in 100 g almonds)
- Almonds are a low-moisture food
    - ~3–6% moisture is a common industry standard for almonds (raw, blanched, cut)
    - <3% moisture is typical for roasted almonds

Water activity (a_w): the water activity is a measure of the *available* water in a product. Water that associates more strongly with components in a food is not as available for chemical and enzymatic reactions or to support microbial growth. Most bacteria and molds will not grow at a_w<0.8.

- in low-moisture foods like almonds, a_w is dependent on the relative humidity of the storage environment and temperature
- a_w levels of ~0.3–0.6 are typical for almonds stored at cool and dry conditions



3.2 Lipid oxidation & rancidity

Peroxide value (PV). Peroxides are the main initial breakdown products formed when fats, especially unsaturated fats, react with oxygen (lipid oxidation).

- PV is useful as an indicator of peroxide formation at the *early stages* of oxidation
  - As oxidation progresses, PV will peak and then decline as the peroxides quickly break down, so a low PV is not always a sign of freshness or good quality. PV values along with other key measurements are needed.
- PV is expressed as meq/kg (milliequivalents of peroxide per kg oil)
- PV<5.0 meq/kg is a common industry standard for almonds

Conjugated dienes (CD). Conjugated dienes are carbon compounds (with two double bonds separated by a single bond) produced when polyunsaturated fatty acids break down during the initial stages of lipid oxidation.

- CD determination is less sensitive than PV measurement, but can be correlated with PV
- CD is measured by absorbance of UV light at 232–234 nm
- No common industry standard currently exists for CD

Free fatty acids (FFA). The breakdown of free fatty acids can lead to rancidity. Fatty acids are released from fat molecules by the action of naturally occurring enzymes known as lipases. Lipases in raw almonds may be activated when the moisture content is above the critical level (>6%).

- FFA is useful as an indicator of hydrolytic rancidity
- FFA is expressed as % (percent)
- <1.5% FFA is a common industry standard for almonds

Hexanal. Hexanal is a major secondary product of lipid oxidation. Hexanal, an aldehyde, is one of many volatile compounds formed as lipids oxidize during storage and can be measured by chemical methods.

- Hexanal is commonly used as an indicator of oxidative rancidity
- No common industry standard currently exists for hexanal in almonds

Other volatiles. Roasting of almonds develops desirable flavor and aroma compounds, but also promotes lipid oxidation reactions that can lead to rancidity. A wide range of volatile compounds exist in raw, roasted, and stored almonds. Research is ongoing to establish and monitor the profiles of volatile compounds in almonds upon roasting and during storage. To date, specific groups of volatiles have been identified that could be used as sensitive markers of early oxidation.

- No common industry standards currently exist for volatiles in almonds

Sensory evaluation. Laboratory tests for oxidation and rancidity all have limitations. In addition to laboratory tests on almonds, it is useful to also do sensory evaluation of the descriptive flavors and odors associated with lipid oxidation (e.g., cardboard, painty, and rancid).

4. References and Further Reading

Altan, A., K.L. McCarthy, R. Tikekar, M.J. McCarthy, N. Nitan. 2011. Image analysis of microstructural changes in almond cotyledon as a result of processing. *J. Food Sci.* 76(2):E212–E221.

Fennema, O. (ed.). 1996. *Food Chemistry*. Marcel Dekker, Inc., NY.

Lin X., J. Wu, R. Zhu, P. Chen, G. Huang, Y. Li, N. Ye, B. Huang Y. Lai, H. Zhang, W. Lin, J. Lin, Z. Wang, H. Zhang, R. Ruan. 2012. California almond shelf life: lipid deterioration during storage. *J. Food Sci.* 77(6):C583–C593.

Miller, M. 2010. Oxidation of food grade oils. *Plant and Food Research, New Zealand*. Available at: http://www.oilsfats.org.nz/Oxidation%20101.pdf.

Taitano, L.Z., R.P. Singh. 2012. Moisture adsorption and thermodynamic properties of California grown almonds (varieties: Nonpareil and Monterey). *Int. J. Food Stud.* 1:61–75.

Taitano, L.Z., R.P. Singh, J.H. Lee, F. Kong. 2012. Thermodynamic analysis of moisture adsorption isotherms of raw and blanched almonds. *J. Food Process Eng.* 35(6):840–850.

Xiao, L., J. Lee, G. Zhang, S.E. Ebeler, N. Wickramasinghe, J. Seiber, A.E. Mitchell. 2014. HS-SPME GC/MS characterization of volatiles in raw and dry-roasted almonds (*Prunus dulcis*). *Food Chem.* 151:31-39.