Hot Air Roasting of Almonds

Summary

Hot air (dry) roasting is a thermal process suitable for almonds and other tree nuts. Roasting changes the flavor profile of the almonds and results in a brown color and a crunchy texture. Light-, medium-, or dark-roasted products are achieved with specific temperature-time roasting treatments. Flavor composition and intensity depend on the roasting conditions. Hot air roasting temperatures used for almonds in California typically range from ~130 to 154°C (~265 to 310°F). Almonds are rich in unsaturated fatty acids, but the high degree of unsaturation makes almond oil susceptible to oxidation during processing and storage. Oxidative reactions degrade the quality of roasted almonds and limit their shelf life. The use of lower hot air roasting temperatures helps to preserve the almond microstructure and maximizes shelf life. Hot air roasting for almonds can be optimized by applying a two-step roasting process. The first step uses an intermediate temperature to stabilize the nut microstructure, and the second step uses a higher temperature to generate the desired flavor and color. This summary highlights the latest research on hot air roasting technology and proposes optimal almond processing and handling.

Contents

1. Introduction

Almonds contain about 50% lipids (oil) by weight (*USDA, 2013*), which are susceptible to oxidation reactions in the presence of oxygen and light. Lipid oxidation causes unacceptable off-flavors and off-odors, reducing product shelf life. The rates of oxidation increase after roasting. Proper storage and handling pre and post process will help maximize quality.

2. Raw almond handling

Cool (<10°C or <50°F) and dry (<65% relative humidity) are the optimal storage conditions for almonds. A storage temperature below 10°C will minimize respiration and reduce the rate of deteriorative reactions. A relative humidity range from 55–60% in the storage environment will maintain the almonds at 5–6% moisture content.

3. Hot air roasting

3.1. Overview of almond texture, color, and flavor changes

During roasting, moisture evaporates from the almonds, resulting in a crunchy texture. Also, a complex reaction between sugars and amino acids or proteins takes place, known as non-enzymatic browning or

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the Maillard reaction. Non-enzymatic browning of almonds leads to the formation of brown or colored compounds that modify the skin color and also generate a golden or dark brown color within the kernel. During non-enzymatic browning many different volatile or non-volatile reaction compounds are formed. More than 300 flavor compounds that are generated during non-enzymatic browning and contribute to typical roast flavor have been described for almonds and other tree nuts (*Perren, 1995; Perren and Escher, 2007*).

The kinetics of roast flavor development depend largely on temperature, nut moisture content, and time.

3.2. Heat transfer during roasting

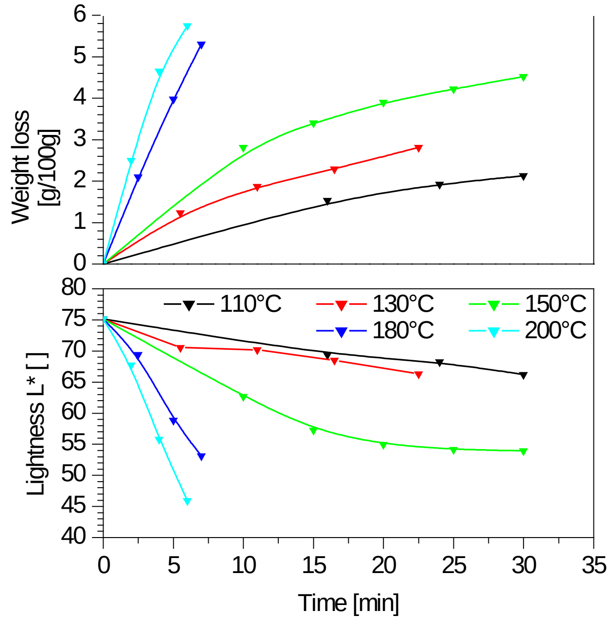
Hot air roasting is a convective heat transfer process. During hot air roasting, the nut temperature rises continuously as a function of heat transfer and the temperature of the almonds rises to far above 100°C (212°F). As the nut temperature approaches 130°C (266°F), the rate of temperature increase slows as moisture evaporation accelerates. Almond moisture content decreases to 2% or less during roasting.

3.3. Influences of roasting temperature

<u>Effects on almond weight loss, moisture content, and color</u>

The temperature during hot air roasting influences the rate of change in weight loss, moisture content, and color (lightness, L*). There is a strong correlation between weight loss and change in moisture content upon roasting because weight loss is largely caused by moisture evaporation (Figure 1).

Figure 1: Influence of roasting temperature on kernel weight loss and lightness.



<u>Effects on microstructure</u>

Almonds are seeds and store energy (primarily in the form of lipids) needed for germination. Almonds have a highly compartmentalized microstructure that protects lipids from environmental oxygen and oxidation. The lipids in almonds are present as intracellular oil droplets stored in small globular structures called oleosomes, approximately 1 to 2 µm in diameter, which are protected by a monolayer membrane (Figure 2) (*Perren, 1995; Young et al., 2004*). The oleosomes are separated from each other by a membrane network that forms a honeycomb structure. The subcellular organization in raw almonds protects the oil from oxygen access so there is less substrate available for oxidation.

Figure 2: Diagram showing the microstructure of an almond cell.

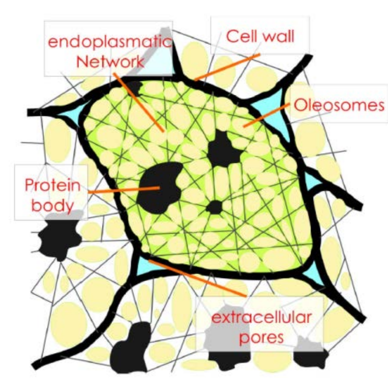
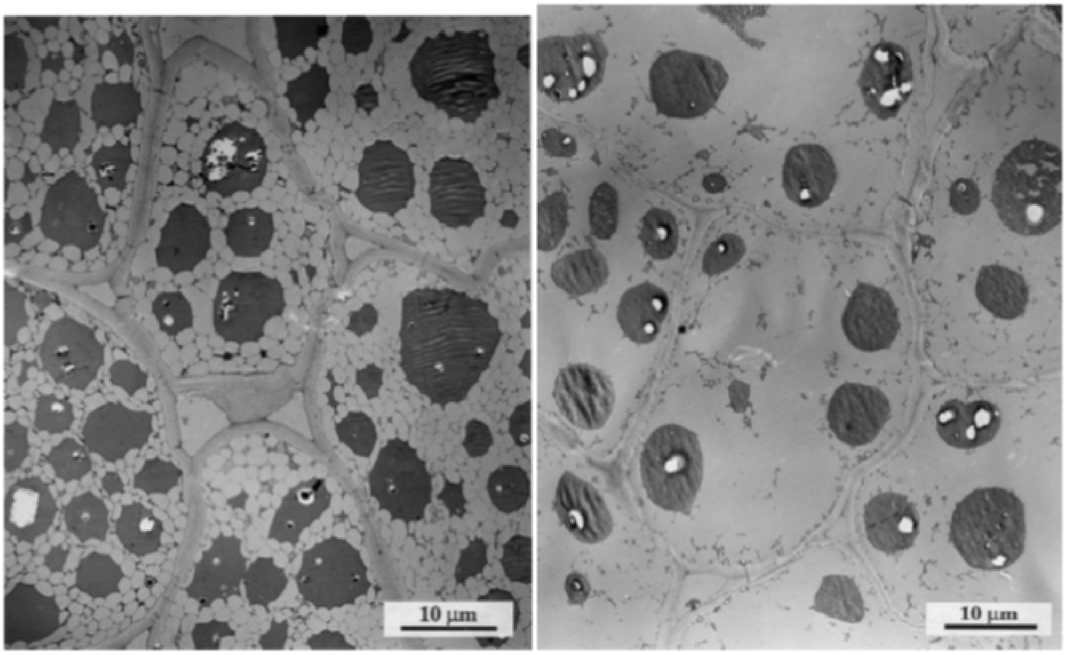


Figure 3. TEM micrographs of almonds before (left) and after (right) roasting at 150°C for 15 min.



During roasting, however, the oleosomes burst, the membrane network is destroyed, and the volume of extracellular pores enlarges (Figure 3). The loss of compartmentation and the accompanying increase in porosity accelerate oxygen transfer and oxidation. These changes in almond microstructure are mainly influenced by the product temperature during roasting and to a lesser extent by roasting time.

To dry roast almonds, hot air temperatures should be as low as possible to preserve the native microstructure and to maximize shelf life (*Perren and Escher, 2013*). Another strategy designed to improve shelf life includes the use of a two-step hot air roasting process, as discussed in 3.4 below.

3.4. Industrial roasting systems

To achieve high quality roasted almonds, a roasting process must meet the following requirements:

- Heat treatment must be uniform.
- Heat treatment must provide consistent quality in color, flavor, and texture.
- Roasting equipment must transfer only minimal mechanical energy to the nuts to preserve integrity and appearance.

The development of roasting equipment and processes has been driven mainly by technical innovation. A wide range of hot air roasting systems is available, including continuous roasters (single belt convection roasters, vertical continuous roasters, continuous drum roasters, etc.) and batch roasters (semi-fluidizing batch roaster, drum roasters, ball roasters, etc.).

Continuous roasters are usually limited in terms of roasting temperatures and times, but may be preferable if variations in product and roasting degree are of minor importance. Batch roasters are very versatile and are often able to achieve a wide range of roasting degrees and product qualities. With modern control systems, batch processes can be run in a quasi-continuous manner, eliminating the operational differences between batch and continuous systems.

Uniform heat transfer

Roasting requires a sufficiently high energy transfer rate. To avoid temperature differences that lead to color differences among the nuts, it is essential to either mix the nuts, as in rotary drum or ball roasters, or to distribute the energy uniformly through the nuts. However, mechanical action in rotary roasters may impair the surface structure of almonds, causing release of oil.

Cooling

Cooling must be considered part of the roasting process. A rapid air-cooling process is essential to stop the roasting reactions after processing is complete. The roasted product must be cooled to below 25–30°C (77–86°F) to limit oxidation during storage. The product should not be packed and sealed if the product temperature is above 30°C (86°F) because moisture may condense on the inner surface of the package.

Two-step hot air roasting process

Hot air roasting for almonds and other tree nuts can be optimized by applying a two-step roasting process. The first step uses an intermediate temperature to stabilize the nut microstructure, and the second step uses a higher temperature to generate the desired flavor and color. In the two-step roasting process, microstructure degradation during roasting is reduced, which in turn leads to increased oxidative stability.

The two-step roasting process is achieved with a semi-fluidizing hot air batch roaster (Bühler Barth AG) and has been successfully commercialized and installed worldwide. More than 100,000 tons of nuts can be processed per year with this two-step roasting system.

Improved oxidative stability by the two-step roasting process compared to traditional industrial hot air roasting processes has been clearly demonstrated for almonds, hazelnuts, and peanuts in many industrial scale trials comparing different nut types and varieties, roasting processes, and roasting degrees. In all trials investigated, nuts roasted with the two-step process exhibited superior shelf stability compared to nuts roasted with a traditional hot air process.

4. Downstream processing and packaging

Shelf life expectations for roasted nut products should be considered in downstream processing. Because oxidation starts immediately after roasting, roasted nuts are unstable goods and so any further processing should be done as quickly as possible.

Mechanical treatment and transport systems are additional issues for roasted nuts. Due to low moisture content, roasted almonds are susceptible to mechanical damage, leading to damaged surface structures and oil leakage. Therefore, only minimal downstream processing that affects appearance and surface integrity should be applied.

For chocolate production and dicing applications, the roasted nuts must first reach a suitable temperature. For applications using ground roasted nuts, the oxidative stability of the oil is the predominant concern. Microstructure degradation is not an issue because the cellular structure is completely disintegrated, the oil is the continuous phase, and the surface exposed to air is reduced.

To maximize the shelf life of roasted nut products, proper packaging must be selected. Packaging materials must be non-transparent, and modified atmosphere or vacuum packaging may be used to decrease potential oxidation reactions during storage. In addition, storage at reduced temperatures is ideal to protect lipids and flavors, but products must be protected from condensation when removed from cold warehouses.

5. References

Almond Board of California. 2007. Guidelines for validation of dry roasting processes, v1.2, October 23, 2007. http://www.almondboard.com/Handlers/Documents/Dry-Roast-Validation-Guidelines.pdf.

Federal Register. 2007. Almonds grown in California; outgoing quality control requirements. *Fed. Reg.* 72:15021–15036. Available at: http://www.gpoaccess.gov/fr/retrieve.html.

Perren, R., F.E. Escher. 2013. Impact of roasting on nut quality, pp. 173–197. *In* L.J. Harris (ed.), Improving the safety and quality of nuts. Woodhead Publishing Ltd., Cambridge, UK.

Perren, R., F. Escher. 2007. Nut roasting technology and product quality. *The Manufacturing Confectioner* 87(6):65–75.

Perren, R. 1995. Untersuchungen über das Rösten von Haselnüssen [Investigations of Hazelnut Roasting], Thesis No. 11390, ETH Zürich, Zürich.

USDA. 2013. U.S. Department of Agriculture, Agricultural Research Service. USDA National Nutrient Database for Standard Reference, Release 26. Available at: http://www.ars.usda.gov/ba/bhnrc/ndl.

Young, C.T., W.E. Schadel, H.E. Pattee, T.H. Sanders. 2004. The microstructure of almond (*Prunus dulcis* (Mill.) D.A. Webb cv. 'Nonpareil') cotyledon. *LWT – Food Science and Technology* 37(3):317–322.