Almond

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Scientific Name and Introduction: *Prunus amygdalus* is a member of the family Rosaceae. The sweet cultivated almond originated from bitter-seeded species that evolved in the deserts and foothills of central and southwest Asia. Almonds have been cultivated for over 4000 years, and starting about 450 BCE were cultivated around the Mediterranean coastline from Turkey to Tunisia. Almonds were first introduced to California through the missions, but the large commercial industry was initiated from trees brought with settlers from the eastern U.S. that have thrived in the Mediterranean climate of the Central Valley of California (Kester and Ross, 1996).

The edible kernel (primarily two cotyledons whose cells are filled with oil bodies and a small embryo) is surrounded by a shell and hull tissue. Almonds are relatively high in oil content; with values ranging from 36 to 60% of kernel dry mass (Abdallah et al., 1998; Guadagni et al., 1978). Most of the fatty acids in almond oil (about 90%) are unsaturated, with the ratio of monounsaturated to diunsaturated ranging from 2:1 to almost 5:1 (Abdallah et al., 1998). There are hard and soft shell varieties; the soft-shell varieties are the basis of the industry. Nuts are dislodged from the tree by shaking and allowed to dry on the ground before being swept into windrows, picked up and transported to the huller. Some harvested nuts are dried after removal from the orchard (Thompson et al., 1996). This is common if late season rains threaten a delay in harvest. If limited huller capacity leads to stockpiling of nuts, they will likely be covered and subjected to periodic fumigation to limit insect damage. Nuts must be dried to < 10% moisture prior to stockpiling.

Quality Characteristics and Criteria: In-shell almonds should have hulls that are uniform, with a bright color and be free of adhering hull material or debris. The hull should be intact, free of damage caused by the hulling operation, insects or fungi. Kernels should be fully formed rather than shriveled. Kernels of larger size are preferred. The "skin" of the kernel should be unbroken (free of damage caused during shelling or by insects or pathogens) and of uniform dark brown color. Almond flavor should display a combination of sweet and oily notes. There should be no stale or rancid flavors. Optimal kernel texture is from crisp to chewy. Kernels should have < 8% moisture, but kernels with < 4% moisture tend to be brittle and hard (Kader, 1996). Currently over 95% of the California almond crop is sold as shelled products, but developing export markets include substantial interest in in-shell product.

Caveletto et al.(1985) used an assortment of physical, chemical and sensory methods to evaluate the quality attributes of 23 almond varieties in terms of their use as in-shell, raw, roasted and blanched nuts. Composition of fats and sugars were determined, flavor notes and textural characteristics were described, and the ability to tolerate processing procedures and suitability for various products were evaluated.

Horticultural Maturity Indices: Almond maturation can be monitored externally by evaluating the extent of hull dehiscence. In the absence of pressure from insects like the naval orangeworm (*Amyelois transitella*), harvest can be delayed until the two halves of the hull are fully bent back to expose the shell. At this point, hulls readily separate from the hull and moisture content is low enough that nuts can be immediately picked up from the orchard floor. Yield is maximized because the kernel's dry weight is no longer increasing and nut removal is close to 100%. Nut maturation on a given tree is not uniform; development tends to be most rapid on the south and southwestern faces of the tree higher in the canopy.

The California industry favors a timely (early) harvest that limits naval orangeworm egg laying in split hulls. Thus, harvest should be matched to the time that the last nut on a tree has begun to split. Nut removal can be near maximum, and minor decreases in kernel size are acceptable due to reductions in insect damage (Connell et al., 1996; Reil et al., 1996). Early harvested nuts (hulls and kernels) contain more water than is acceptable and must be dried on the orchard floor for 1 to 2 weeks before they are picked up and hulled.

Grades, Sizes and Packaging: In-shell and shelled grades are defined by USDA standards. For the in-shell product, emphasized characteristics include the integrity, shape and hardness of the shell as well as the brightness and uniformity of its color. Freedom from foreign material and signs of insect damage or decay are also important. The shelled almonds should be free of shell debris and foreign material, and insect or fungal damage. The kernel skin should be intact and should show no shriveling or discoloration. Double, split or broken kernels are negative factors. There should be no indication of rancid flavor. A complete description of federal quality standards can be found at: http://www.ams.usda.gov/standards.nutpdct.htm.

Optimum Storage Conditions: The low water and high fat content of the kernel make it relatively metabolically stable and able to tolerate low temperatures. The primary objectives of storage regimes are to maintain the low water content. Federal regulations define a safe moisture level for nuts as a water activity < 0.7 at 25 °C (77 °F) to retard microbial growth. The recommended storage RH is 65% because too low a water contents negatively impact flavor, color and texture (Kader, 1996). Cold storage is useful to minimize lipid oxidation (rancidification). In-shell almonds can be stored for up to 20 mo at 0 °C (32 °F), 16 mo at 10 °C (50 °F), and 8 mo at 20 °C (68 °F). Shelled nuts can be stored for about half as long as nuts in the shell (about 6 mo), and pieces for even less. Almonds should not be stored with commodities that have strong odors because their high lipid content allows them to readily absorb odors.

Modified Atmosphere Considerations: Kernels are less stable than in-shell almonds, and better fresh almond flavor is maintained in a low O_2 and elevated CO_2 atmosphere. Flavor was maintained for 12 mo at 18 and 27.5 °C (64.5 and 81.5 °F) in insect-controlling atmospheres of < 1% O_2 and 9 to 9.5% CO_2 (Guadagni et al., 1978). Reduction in the O_2 content of the storage atmosphere will improve oil stability. The stability difference between in-shell nuts and shelled kernels was eliminated in 0.5% O_2 (Kader 1996).

Chilling Sensitivity: Almonds are not sensitive to chilling temperatures.

Ethylene Production and Sensitivity: Almonds produce very little ethylene. Although almond dehiscence and abscission are hastened by exposure to ethylene (Weis and Labavitch, unpublished results), there are no documented responses to ethylene that might directly affect kernel quality.

Respiration Rates: The low water content of properly stored kernels makes them relatively inert metabolically. Respiratory rates are very low.

Physiological Disorders: Two important quality problems of almond kernels are influenced by failure to maintain low water content. Harvested nuts are often stockpiled and fumigated to control naval orangeworm prior to hulling and shelling. Temperatures in covered stockpiles that are open to the sun can reach 60 °C (140 °F). If nuts have not been dried to < 10% moisture in the orchard, or have been wetted by late-season rains, they should not be fumigated. The combination of elevated moisture and temperature leads to a problem called concealed damage, which is marked by inversion of sucrose, lipid oxidation and internal kernel darkening. Elevated temperature alone does not cause the problem and forced air drying of rain-wetted kernels can prevent it. Wetting of freshly harvested almonds followed by heating can cause the problem. However, almonds that have been held in dry storage for several months and then wetted and heated do not develop the problem (Reil et al., 1996). Another kernel quality problem is premature sprouting (growth of the embryo between the unopened cotyledons). While the almond kernel's content of polyunsaturated fatty acids is much less than walnuts or pecans, failure to maintain proper storage lead to rancidification. Factors contributing to rancidification were studied by Zacheo et al. (1998).

Postharvest Pathology: Most infections with pathogens are initiated in the orchard, and because clean-up following harvest is not absolute, the potential problems are transferred to the postharvest environment. In-shell product is relatively protected unless the shell has been broken or penetrated by insects. The most serious pathogens are fungi such as *Aspergillus flavus* and *A. parasiticus* which can produce aflatoxins that are both toxic and carcinogenic. Damaged kernels must be discarded prior to storage and low temperature and RH conditions must be maintained. Phillips et al. (1979) and King Jr. et al. (1983) have described the variety of fungi (primarily *Aspergillus* spp., but also *Alternaria*, *Rhizopus*, *Cladosporium* and *Penicillium* spp.) that are found on almonds, and the latter work and King Jr. and Schade (1986) have described the impact of storage of kernels at various water activities and temperatures on the competition between these fungi. Because of the relationship between insect damage and pathogen presence, sorting to eliminate whole kernels with insect damage will reduce the number of whole kernels with excess levels (>1 ng/g) of aflatoxins. However, lower grades and broken kernels or kernels sold as animal feed or processed for oil can still present problems (Schatzki, 1996). Sampling of kernels to test for aflatoxin presents statistical problems because contamination is centered in individual kernels.

Quarantine Issues: The most serious almond postharvest insect problem is with naval orange worm. The insect lays its eggs in newly split nuts, just prior to harvest and the resulting larvae can cause substantial losses. Fumigation with methyl bromide, which has a limited future, or phosphine is used to control the insect. In-home control of insects can utilize treatment at freezing temperatures of -5 to -10 °C (14 to 23 °F) for a few days. Irradiation can also be used (30 kilorad). The most useful, non-chemical insert control approach appears to be a < 1% O_2 and 9 to 9.5% CO_2 CA regime (Guadagni et al., 1978).

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