Pistachio

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Scientific Name and Introduction

Pistacia vera L. is the only species of the 11 in the genus *Pistacia* that produces edible nuts. It is a native of western Asia and Asia Minor, and wild representatives are still found in hot, dry locations in these areas. The pistachio was introduced to Europe at the beginning of the Christian Era. The USDA plant exploration service introduced the pistachio to the United States in 1890. It was introduced to California in 1904 at the Plant Introduction Station in Chico, CA (Hendricks and Ferguson 1995).

The pistachio tree is dioecious; thus orchard plantings must include the appropriate ratio of females and males (8:1 in older plantings, but up to 25:1 in more recently established orchards [Kallsen et al. 1995]). At present the California industry is dominated by one male cultivar ('Peters') and one female ('Kerman'), although other cultivars are being tested. The reliance on single cultivars poses the potential for catastrophic problems for the industry with pests and diseases, and efforts to evaluate existing alternative germplasm and develop new cultivars are underway (Parfitt 1995a,b). There are also a limited number of rootstocks in use. While the *Verticillium*-tolerant *Pistacia integerrima* is currently the dominant rootstock in use, *P. atlantica* × *P. integerrima* is increasingly being planted in California (Krueger and Ferguson 1995). An important problem for pistachio growers is the strong tendency toward alternate bearing.

Quality Characteristics and Criteria

In-shell and shelled pistachios are marketed extensively. An important aspect of quality of the in-shell product is a shell that is free of staining. This is not only for cosmetic reasons. Shell staining is also an indicator of development, pathogen, and insect problems prior to harvest. Kernel quality criteria include a firm, crisp texture (which is degraded by insufficient drying after harvest or storage at too high an RH), a sweet and oily flavor, and freedom from rancidity (Kader et al. 1982). Kernels are high in fat content (approximately 45% by weight) and crude protein (approximately 30%). Total levels of low-molecular-weight sugars are 3 to 4%, but reducing sugars (primarily glucose and fructose) make up only about 10% of the total sugar (Kader et al. 1982, Labavitch et al. 1982).

Horticultural Maturity Indices

The pistachio nut is a drupe; an exocarp and fleshy mesocarp surround the hard, but relatively thin, shell, which encloses the edible seed. Ideally the harvest is timed to the full accumulation of fat and sugar in the kernels. This is roughly coincident with the splitting of the shell. Shell split is not visible due to the fact that the fleshy mesocarp masks the shell in developing nuts. However, evidence of maturation can be seen in the color change of the hull (exocarp), which is green when the nut is not mature and then progresses through ivory to rose with full maturation. Activity in the abscission zones between the nuts and the rachis (assessed by a measurable decrease in "fruit removal force") also indicates maturation. When fully mature, the nut with its shell will be ejected from the hull when pressure is applied with the thumb and forefinger at the hull's distal end (Ferguson et al. 1995). Nuts at full maturity, as judged by the preceding criteria, will have full accumulation of fat and simple sugars (Labavitch et al. 1982).

Harvest should not be delayed past full maturation of the crop because this will increase losses to navel orangeworm (*Amyelois transitella* Walker), birds, and fungi (particularly *Aspergillus flavus*), as well as late season weather (rain and wind). Furthermore, delayed harvest can lead to shell staining because of breakdown of the phenolic-compound-rich hull tissues. When harvested the nuts are split and moisture content is high (40 to 50%). Trees are shaken (by hand for young trees, mechanically for mature trees) and the nuts are caught on tarps or a catching frame and transferred to bins in order to eliminate problems caused by contact with the soil.

Delays between harvest and further processing should be minimized because they only exacerbate problems caused by hull breakdown or contamination of hull tissues. Problems caused by unavoidable delays in hulling and drying (below) can be reduced by cold storage of bins at 0 ºC (32 ºF) and <70% RH without increasing shell staining (Kader et al. 1980, Thompson 1997). At the processor, the bins of nuts are dumped, and debris is removed by passage over an air leg. Hulls are removed, blanks are removed in a float tank, and the in-shell nuts are dried to 5 to 7% moisture. Most large handlers now use a two-stage process: Nuts are dried in a column dryer to 12 to 13% moisture with forced hot air at 82 ºC (180 ºF) before the drying is completed more slowly (24 to 48 h) with air heated to no more than 49 ºC (120 ºF) (Ferguson et al. 1995).

Grades, Sizes, and Packaging

In-shell and shelled grades exist and are determined primarily by kernel size, degree of dryness, absence of foreign material, and freedom from defects caused by insects and mold. For the in-shell product, additional grading criteria include absence of shell pieces and free kernels, shells without stains and adhering hull material, and absence of unsplit shells and blanks. A complete description of U.S. quality standards, grades, and sizes for pistachios in the shell can be found at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050502.

Shell staining is usually caused by dehiscence of the hull along its suture at the same time as the shell within is splitting. This premature hull dehiscence increases "early" problems with insects and molds (Doster and Michailaides 1999). Pearson (1996) and Pearson and Slaughter (1996) described testing of a machine vision system that might prove useful in sorting of nuts in processing streams to reduce the incidence of staining in the marketed product. The simultaneous splitting of shell and hull is generally caused by too tight an adherence of the hull to the shell. The absence of a tissue gap between the two pericarp-derived parts of the nut makes it impossible for the shell to split without triggering hull split. This often leads to shells with adhering hull material (Pearson et al. 1996), considered a defect.

Optimum Storage Conditions

Once they have been dried (see above), nuts can be held at 20 ºC (68 ºF) and 65 to 70% RH for up to a year (Ferguson et al. 1995). Pistachios are considerably less prone to rancidification (precipitated by oxidation of polyunsaturated fatty acids) than are almonds and, particularly, pecans and walnuts. These commodities are also high in fat content, but walnut and pecan oils have a much higher content of polyunsaturated fatty acids than pistachio oil.

Controlled Atmosphere Considerations

While relatively stable when stored in air at 20 ºC (68 ºF), storage under high CO_2 (Maskan and Karatus 1998), reduced O_2 (<0.5%), and lower temperature (0 to 10 ºC) further improve flavor stability with the added benefit of providing insect control. Vacuum packaging or N_2 flushing of packages also provides benefits.

Chilling Sensitivity

Pistachios are not sensitive to chilling and can be stored at or below freezing.

Ethylene Production and Sensitivity

Pistachio production of ethylene is very low. There are no documented responses to ethylene that might affect nut quality.

Respiration Rates

The low water content of properly stored, dried pistachios makes them relatively inert metabolically. Respiratory rates are very low.

Physiological Disorders

Rancidification and shell staining have been discussed in previous sections.

Developmental and physiological problems that occur before full maturity can have particularly important consequences for nut quality. Because nuts are only useful when they have split, failure of hull split as nuts reach full maturity can cause substantial yield losses. While splitting is maturation-dependant, it will be reduced by water stress late in the growing season (mid-August through September) and failure to maintain adequate boron (120 ppm [mg kg^{-1}] leaf dry weight). Early in postharvest drying, the split on partially split nuts tends to widen (Freeman and Ferguson 1995).

Blank nuts result when the embryo fails to develop. This can be caused by promotion of shell development from ovary tissues without successful fertilization. Blank development also occurs later in the season and has been explained as the result of the inability of the tree to provide sufficient assimilate to complete development of its entire crop. Inadequate boron and water stress are also indicated as causes of blank formation (Freeman and Ferguson 1995).

Pistachios are strongly alternate-bearing and failure of hull split and blank formation are correlated with “on” and “off” crop years. Studies indicate that blanking tends to be much higher in “off” years and nonsplit nuts are much more common in “on” years. Of course, crop load is much higher in “on” years, and this has a large effect on assimilate partitioning.

Insect Problems

Several insects that are field pests of pistachios are able to cause superficial damage (“epicarp lesion”) to developing nuts. If insects are able to probe deeply or introduce fungal pathogens, these pests can cause damage to the kernels. The navel orangeworm (*Amyelois transitella* Walker), a primary field pest, is the major insect problem after harvest. Methyl bromide fumigation has been used to control navel orangeworm in harvested pistachios (Hartsell et al. 1986), but this fumigant is being phased out. Laboratory tests of navel orangeworm survival during pistachio processing indicate that very few of the insects survive nut-drying (Johnson et al. 1996). Projections indicate that survival of navel orangeworms is insufficient to be a problem in stored nuts, particularly because reinoculation of nuts due to insect reproduction within the dried, stored nuts is likely to be virtually nonexistent (Johnson et al. 1996).

Postharvest Pathology

Several fungi are capable of infecting growing pistachio nuts and causing damage to hulls and kernels. Infection is often facilitated by early splitting of hulls, which leads to infestations by a number of hemipteran insects that feed on the nuts and serve as nonspecific vectors for diseases. *Alternaria* and *Cladosporium* species are also colonizers of early split nuts. Late season rains will promote activity of *Botryosphaeria dothidea* on pistachio hulls and kernels (Michailides et al. 1995). Because mold counts on nuts going into storage can be high (Heperkan et al. 1994), it is important that proper storage conditions (especially low RH and absence of standing water) be maintained to avoid serious problems.

The greatest postharvest disease threats are from *Aspergillus flavus* and *A. parasiticus*. The danger is particularly serious because these fungi can produce aflatoxin. As with many disease problems of pistachio, vectoring by insects attracted to early split nuts (such as navel orangeworm) is an important contributing factor. In Doster and Michaelides’ (1994) study of *Aspergillus* molds in California pistachios, early split nuts had over 99% of the aflatoxin detected and navel-orangeworm-infected nuts had substantially more infection by several *Aspergillus* species, as well as over 84% of the aflatoxin detected. The close association of contamination with early split nuts suggests that the potential aflatoxin problem can be reduced by following procedures for reducing early splitting or sorting out nuts with shells stained because of early splitting (discussed above and Michaelides et al. 1995). In theory, nuts with aflatoxin contamination could be sorted out based on aflatoxin fluorescence; however, Steiner et al. (1992) concluded that this approach may have limited value because of limited sensitivity of detection and inconsistent presentation of fluorescence in contaminated nuts. Further complicating the detection problem is the fact that substantial contamination in a large sample of nuts may be due to the initial contamination and spread by only a few individual nuts.

Quarantine Issues

Insect infestation is a potentially important problem, as are the fungal infections that often accompany insect damage. Fumigation with methyl bromide or phosphine has been used for disinfestation, but the former is being curtailed and insect resistance to phosphine has been reported (Zettler et al. 1990). New fumigants are being developed and tests of efficacy, including effects on flavor, are being performed (E.J. Mitcham, Univ. of California, Davis, 2002, personal communication). Thus far, the newer fumigants are not registered for pistachio nuts.

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