Pistachio

John M. Labavitch
Pomology Department, University of California, Davis, CA

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 U.S. 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 is also a limited number of rootstocks in use. While the Verticillium-tolerant *Pistacia integerrima* is currently the dominant rootstock in use, *P. atlantica* x *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 developmental, pathogen and insect problems prior to harvest (discussed further in Grades etc., below). Kernel quality criteria include a firm, crisp texture (which is negatively influenced by insufficient drying after harvest or storage at too high a RH, below), a sweet, oily flavor, and freedom from rancidity (Kader et al., 1982). Kernels are high in fat content (apx. 45%, by weight) and crude protein (apx. 30%). Total low molecular weight sugar levels are 3 to 4%, but reducing sugars (primarily glucose and fructose) represent 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 (NOW, *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 these 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) at < 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 wherein nuts are dried in a column dryer to 12 to 13% moisture with forced hot air at 82 ºC (180 ºF) and 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 primarily determined 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 federal quality standards, grades and sizes can be found at: http://www.ams.usda.gov/standards.nutpdct.

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) have described testing of a machine vision system that might prove useful in sorting of nuts in processing streams so as 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, PUFA) 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 PUFA 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 improves 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 temperatures 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, ie., 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/physiological problems that occur prior to the attainment of 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, 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 later in the season also occurs 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 non-split nuts are much more common in “on” years. Of course, crop load is much higher in “on” years, and this has a large impact on assimilate partitioning.

Problems with Insects: 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 (NOW; *Amyelois transitella* Walker), a primary field pest, is the major insect problem after harvest. Methyl bromide fumigation can been used to control NOW in harvested pistachios (Hartsell et al., 1986), but the use of this fumigant is being phased out. Laboratory tests of NOW survival during pistachio processing indicate that very few of the insects survive nut drying (Johnson et al., 1996). Projections indicate that survival of NOW 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 non-existent (Johnson et al., 1992).

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 which feed on the nuts and serve as non-specific 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, absence of standing water) be maintained to avoid serious problems.

The greatest postharvest disease threats are from *Aspergillus flavus* and *A. flavus*. The danger is particularly serious because these fungi can produce aflatoxin. As with many disease problems of pistachio, vectoring by insects, eg., NOW, attracted to early split nuts is an important contributing factor. The their study of *Aspergillus* molds in California pistachios, Doster and Michaelides (1994), early split nuts had over 99% of the aflatoxin detected and NOW-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 reduction of the potential aflatoxin problem can be had 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) have 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 contamination of only a few individuals.

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 use of 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 (E.J. Mitcham, UC-Davis, personal communication), are being performed. Thus far, the newer fumigants are not registered for pistachio nuts.

References:

Doster, M.A. and T.J. Michailaides. 1994. *Aspergillus* molds and aflatoxins in pistachio nuts in California. Phytopathology 84:583-590.

Doster, M.A. and T.J. Michailaides. 1999. Relationship between shell discoloration of pistachio nuts and incidence of fungal decay and insect infestation. Plant Dis. 83:259-264.

Ferguson, L., A. Kader and J.Thompson. 1995. Harvesting, transporting, processing and grading. In:

Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA, pp. 110-114.
Freeman, M. and L. Ferguson. 1995. Factors affecting splitting and blanking. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA, pp. 106-109.
Hartsell, P.L., H.D. Nelson, J.C. Tebbets and P.V. Vail. 1986. Methyl bromide fumigation treatments for pistachio nuts to decrease residues and control navel orangeworm (*Amyelois transitella* (Lepidoptera: Pyralidae). J. Econ. Entomol. 79:1299-1302.
Hendricks, L. and L. Ferguson. 1995. The pistachio tree. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA, pp. 7-9.
Heperkan, D., N. Aran and M. Ayfer. 1994. Mycoflora and aflatoxin contamination in shelled pistachio nuts. J. Sci. Food Agric. 66:273-278.
Johnson, J.A., R.F. Gill, K.A. Valero and S.A. May. 1996. Survival of navel orangeworm (Lepidoptera: Pyralidae) during pistachio processing. J. Econ. Entomol. 89:197-203.
Johnson, J.A., H.R. Bolin, G. Fuller and J.F. Thompson. 1986. Efficacy of temeprature treatments for insect disinfestation of dried fruits and nuts. Walnut Res. Rpts., 1992:156-171.
Kader, A.A., C.M. Heintz, J.M. Labavitch and H.L. Rae. 1982. Studies related to the description and evaluation of pistachio nut quality. J. Amer. Soc. Hort. Sci. 107:812-816.
Kader, A.A., J.M. Labavitch, F.G. Mitchell and N.F. Sommer. 1980. Quality and safety of Pistachio nuts as influenced by postharvest handling procedures. The Pistachio Assoc. Ann. Rpt, pp. 44-52.
Kallsen, C., G.S. Sibbett and C. Fanucchi. 1995. Planning and designing the orchard. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA, pp. 36-40.
Krueger, B. and L. Ferguson. 1995. Pistachio rootstocks. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA., pp. 41-42.
Labavitch, J.M., C.M. Heintz, H.L. Rae and A.A. Kader. 1982. Physiological and compositional changes associated with maturation of 'Kerman' pistachio nuts. J. Amer. Soc. Hort. Sci. 107:688-692.
Maskan, M. and S. Karatas. 1998. Fatty acid oxidation of pistachio nuts stored under various atmospheric conditions and different temperatures. J. Sci. Food Agric. 77:334-340.
Michaelides, T., D.P. Morgan and M.A. Doster. 1995. Foliar and fruit fungal diseases. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA., pp. 148-159.
Parfitt, D. 1995a. Pistachio cultivars. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA., pp. 43-46.
Parfitt, D. 1995b. Genetic improvement. In: Pistachio Production. L. Ferguson (ed) Center for Fruit and Nut Crop Research and Information, Pomology Dept., Univ. Calif., Davis CA., pp. 47-53.
Pearson, T. 1996. Machine vision system for automated detection of stained pistachio nuts. Lebensm.-Wiss. u.-Technol. 29:203-209.
Pearson, T. and D.C. Slaughter. 1996. Machine vision detection of early split pistachio nuts. Trans. Am. Soc. Agric. Eng. 39:1203-1207.
Pearson, T., D.C. Slaughter and H.E. Studer. 1996. Hull adhesion characteristics of early-split and normal pistachio nuts. Appl. Eng. Agric. 12:219-221.
Steiner, W.E., K. Brunschweiler, E. Leimbacher and R. Schneider. 1992. Aflatoxins and fluorescence in Brazil nuts and pistachio nuts. J. Agric. Food Chem. 40:2453-2457.
Thompson, J.F. 1997. Maintaining quality of bulk-handled, unhulled pistachio nuts. Appl. Eng. Agric. 13:65-70.
Zettler, J.L., W.R. Halliday and F.H. Arthur. 1990. Phosphine resistance in insects infesting stored peanuts in the southeastern United States. J. Econ. Entomol. 82:1508-1511.