HARVESTING, TRANSPORTING, PROCESSING AND GRADING

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Substantial crop loss can be sustained during preparation for harvest, in the harvest operation, and during transport to the processing operation. This chapter will discuss how to prevent yield losses and postharvest processing and grading.

PREPARING FOR HARVEST AND HARVEST TIMING

Preparation for pistachio harvest begins in early August with special attention to three factors. The first is irrigation. Pistachio shell splitting is particularly sensitive to irrigation deficits. Therefore, irrigation should be carefully monitored, preferably using budget irrigation methods, through the August and early September shell splitting period. The objective is to maintain adequate soil moisture to maximize shell splitting while insuring the orchard rows will be dry enough to support harvest equipment.

The second factor in harvest preparation is monitoring for *Amyelois transitella*, navel orangeworm (NOW). Infestation by NOW results in unsightly infestation by the larvae and increases the susceptibility of the nut to infestation with *Aspergillus flavus*, the fungus that produces the carcinogen aflatoxin. Depending upon temperatures, calculated as degree days, the third generation of NOW emerges in early to mid-August and lays eggs in the sutures of the early split nuts. In these nuts, the shells split before the hulls dehisce. When the shell splits prematurely, the hull also splits and exposes the kernel to infestation. Though early split nuts are usually no more than 1-5% of a tree's total nut load, an infestation of even 1% of the nuts can produce aflatoxin levels above maximum allowable levels, 20 ppb in the US and the 4 ppb in some European countries. The first step in monitoring for NOW is to assess the quantity of early split nuts. If early splits are higher than one or more nuts per cluster, the early split nuts should be monitored for eggs. If egg-laying is present, the trees should be sprayed with permethrin (Pounce), carbamate (Sevin), or azinphos methyl (Guthion). These pesticides have one-, 14-, and 21-day preharvest intervals, respectively; and harvest must be delayed until the interval has elapsed. Thus, spraying for NOW control must include a harvest date projection.

The third factor of harvest preparation is determining when to harvest. Maturation of pistachio hulls is signaled by color development and is closely linked to shell splitting. As maturity proceeds the hull turns from green to ivory and then to rose, and the shell turns from translucent to opaque. Lack of color development generally signals a blank or aborted nut within the shell. At full maturation the inshell nut will eject easily from the hull when the nut is held between the thumb and forefinger and pressure is applied to the long axis. As these visible changes occur, increases in fat and sugar content cause the kernel moisture, respiration rate and total protein content to decrease and kernel dry weight to increase. The final indication of full maturity is formation of the abscission zone between the nut and its rachis. At maturity nuts will detach readily when the rachis is gently shaken. Optimum harvest time is the two to three weeks bracketing these events and is best indicated by nut removal force.

As with all crops, maturation is uneven throughout the tree. Nuts on the upper southwest quadrant and those on the periphery mature sooner. Light crops also mature earlier than heavy crops. Thus, normal harvesting does not remove all potential crop. However, most nuts remaining in the tree after shaking are blank (empty), or have non-split shells. Ethephon, a foliar compound that hastens and

reduces variability in maturity of some crops, is ineffective on pistachios.

The final factor in harvest timing of pistachios is availability of services: harvesters, transporters and processors. The California pistachio production consists of a single female cultivar, 'Kerman'. Therefore, allowing for climatic differences in the major production areas, the entire statewide crop ripens at about the same time. The harvest season is usually during the month of September. Because pistachios are mechanically harvested and the equipment is seldom owned by the ranches, harvests are contracted and are rapid. And because processors receive from multiple orchards simultaneously, long waits at processor reception are likely. Thus, orchard readiness, and harvest contractor, transportation, and processor availability, must all be coordinated.

Timeliness of harvest is very important in maintaining nut quality. Late harvests increase the potential for a fourth flight of NOW, predation by birds, normal hull deterioration which stains the nut shells, early rains that halt harvest and exacerbate hull deterioration, increases fungal infestation, particularly *Aspergillus flavus*, kernel deterioration, and strong winds that remove nuts. Further, any hull deterioration present at harvest will be exacerbated during transport delays to the processor.

HARVESTING

Harvesting principles are the same for both young and full bearing pistachio trees. The nuts are removed with knocking or shaking onto a catching frame. Because of the high moisture content, 40 to 50% on a fresh weight basis, fragility of their ripe hulls, and open shells within, pistachios are susceptible to mechanical injury and contamination if they drop to the orchard floor. *Aspergillus flavus* is present in wet orchard soils and has the potential to infest pistachios that contact the soil.

Young pistachio trees

Young pistachios, six years and less, are hand harvested. Tarps are spread under both sides of the tree to cover at least 5 feet (1.5 meters) beyond the edge of the canopy on all sides. Nuts are removed by knocking the tree trunk with a padded mallet or striking the branch behind the clusters with a bamboo pole. When nuts cease dropping, the tarps are gathered by the edges and luffed vertically. This brings most of the leaves and lightweight debris to the surface for removal prior to dumping into wood or plastic field bins (4 by 4 by 2 feet = 1.2 by 1.2 by 0.6 meter) with at least 5% of the vertical surfaces occupied by air vents. The bins are dropped off at intervals prior to harvest, picked up, filled and left to be retrieved by bin carriers for forklift loading onto trailers for transport to the processor. A bin can hold 1,000 pounds (450 kilograms) of freshly harvested nuts.

Mature pistachio trees

Unless the crop is too light to justify the cost of machine harvesting, which can occur on the light crop year of this alternate-bearing crop, mature pistachios are mechanically harvested. All pistachio harvesters consist of two separate, self-propelled units about 24 feet (7.5 meters) in length. One unit contains a shaker head that is clamped onto the tree trunk about two feet (0.6 meters) above the ground. This unit mates with the other machine to form a continuous surface under the tree canopy, Plate 18a. Both units have gently sloping wings extending under the canopies into the row middles. After the tree has been shaken for 15 seconds (shake patterns and pressures vary with manufacturers), these wings shake the nuts into the bottom of one catch frame. It then conveys the nuts over an air separator to remove light debris and on the receiver. The major difference in harvesters is in how the nuts are handled after shaking. In a bin system the nuts are collected in pallets that have been placed periodically in the field before harvest. After filling they are collected by mechanical bin carriers to the edge of the field. The bins are either stacked on flatbed trucks or dumped into hopper-bottomed trailers for transport to the processor, Plate 18b. The bulk system consists of carts carried behind the shaker receiver. The carts often have large, central, continuously revolving screws to distribute the crop in the machine. When filled, the carts are unloaded by a continuous transport system or left at the end

of the row to be unloaded bulk trailers by an elevator system. Larger operations generally use a bulk system, as it is a more efficient system for large volumes. Most harvesters can do an acre (0.4 hectares), containing 112 female trees, per hour.

Transport and preharvest storage

Shell staining can increase greatly during postharvest transport and storage, particularly if high levels of hull damage were sustained during harvest. Shell staining generally increases with increased temperatures and increased holding times. Even at night the temperature of nuts held in trailers increases up to 1.1 °F per hour. Nuts with good quality, intact hulls may be held for up to 48 hours at ambient conditions without an increase in staining. Nuts with poor quality hulls will show damage after only eight hours at 104°F (40 °C), 24 hours at 86°F (30°C) and 40 hours at 77°F (25°C).

If delays are anticipated prior to transport or at the processor, keeping the bins or hoppers in the shade will provide some protection. Trailers compared with bins have a greater potential for allowing increases in nut temperature, particularly in the front, bottom area of the trailer. Nuts transported in bins, leaving the orchard at the same time as the bulk trailers, will arrive cooler. Therefore, if the distance to the harvester is particularly long, or delays at the processor are anticipated, bins with at least 5% of the vertical surfaces vented are the preferred mode of transport. Bulk trailers with mesh sides are preferable to solid trailers. If hulling capacity is limited, priority should be given to nuts with the highest internal nut temperatures and poorest hull quality.

If delays over 4 hours occur at the huller, circulating ambient air through bins will prevent the heat increases and nut deterioration for up to two days. Hauling trailers at highway speeds induces air ventilation in the unhulled nuts and cools them. If the anticipated delay is longer than two days, keeping the bins in cold storage at 32°F (0°C) with an airflow of 0.1 cfm per pound (0.1 liters per sec-kg) and less than 70% relative humidity is the best alternative. If possible, sorting before storage to remove debris and damaged nuts that are more susceptible to decay will minimize storage losses. Under these conditions, fresh unhulled pistachios can be held for eight weeks without degradation. However, few processors currently have the needed sorting and cold storage facilities available.

Processing

When pistachios arrive at the processing plant, procedures are conducted as outlined in Table 1.

Previously, most processors used a single-stage drying process using air at 140-160°F (60-71 °C) for 10-14 hours, to achieve 4-6% wet bases moisture. Drying time was controlled by the initial nut moisture and the ambient relative humidity. Drying of pistachios is now generally a two-stage process. It uses less energy and increases the output of the heated air dryer compared with the single stage process. The hulled nuts are first dried to 12-13% moisture in a column dryer, originally designed for grain drying, or a continuous belt dryer, Plate 18c. This requires about three hours at temperatures near 180°F (82°C). Drying air temperatures above this level cause shells to split so widely the nut drops out. A rotating drum dryer, at the same temperatures, can also be used for first stage of drying. In the second stage the nuts are transferred to flat-bottomed grain bins where they are further dried to 4-6% moisture with unheated, forced air, or air heated to less than 120°F (49°C), Plate 18d. This second stage of drying requires 24-48 hours. The nuts can then be stored in these bins until needed for processing. Smaller operations may use bin dryers for single-stage drying. Eight hours at 140-150°F (60-66°C) will produce the desired 4-6% moisture.

Table 1. Processing procedures.

Pistachios delivered in tared flatbed or bulk trailer are weighed and tagged for delivery fresh weight
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Temperature within the load is measured
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Nuts are dumped and conveyed over an air leg to remove debris
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20-pound (9-kilogram) unhulled sample is separated for separate processing and grading
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Hulls are removed from nuts with an abrasive peeler
↓
Blank nuts are separated by float tank and separately dried and stored
↓
Filled split and non-split nuts are dried to 12 - 13% moisture in a high temperature dryer
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Nuts are transferred to grain bins for final drying
↓
Nuts are stored at ambient temperature with forced air flow
↓
Split nuts are separated from non-splits by needle picking drum
↓
Non-splits are shelled or split mechanically
↓
Split nuts are sorted by electronic color reflectance sorter
↓
Split nuts are hand graded to remove defects, debris
↓
Split nuts are salted
↓
Split nuts are roasted
↓
Split nuts are packaged and stored or shipped

In smaller operations, sun drying and ambient air drying may be used. Drying in the sun requires 3-4 days, with protective covering to prevent predation by birds and rodents. Drying nuts in bins with ambient air requires three days if ambient temperatures and relative humidity are sufficient. Nut depth in the bin should not exceed 4.5 feet (1.4 meters), and air should flow at a rate 70 fpm into the bins. The major disadvantage to this method is the potential for fungal growth during the early part of drying.

Storage of dried pistachios

Once dried to 4-6% moisture, but before further processing, nuts can be held at 68°F (20°) and 65-70% relative humidity for up to one year. Other factors that enhance nut quality in storage are exclusion of oxygen and insect control through fumigation, controlled atmospheres or lowered temperatures in the storage bins, and insect-proof packaging. Pistachios are less susceptible to oxidative rancidity compared with other nuts. This may be a result of the lower unsaturated to saturated fatty acids ratio.

The Food and Drug Administration (FDA) has defined "safe moisture levels," the moisture content which will not support fungal growth, as a water activity level that does not exceed 0.70 to 77°F (25°C). This equals a moisture content of about 7%. The relationship between moisture content and equilibrium relative humidity (ERH) is temperature dependent. Between 20 and 80% ERH for any given moisture content, ERH rises about 3% for every 18°F (10°C) rise in temperature.

Lower temperature slows lipid oxidation which results in rancidity, prevents mold growth, and greatly reduces insect activity. Temperatures between 32 and 50°F (0 and 10 °C) are recommended for pistachios depending upon expected storage duration; the lower the temperature, the longer the storage life. Pistachios are more stable and have a longer storage potential than almonds, pecans or walnuts.

Low oxygen atmospheres (<0.5%) aid in maintenance of flavor quality. This procedure is rarely used commercially, but controlled atmosphere storages are available and are used for a few fruit crops. In the final product the atmosphere may be modified by vacuum packaging or by flushing with nitrogen to exclude oxygen.

Insects in stored pistachios can be controlled by fumigation with phosphine. Alternative methods of insect control include insecticidal controlled atmospheres or irradiation. Storage of nuts in 0.5% oxygen and 10% carbon dioxide killed all instars of stored product pests and NOW after 2-5 days at 81°F (27°C). Temperatures near freezing, 32°F (0°C), or between 104 - 120°F (40-50°C) also effectively kill insects. After fumigation the use of insect-proof packaging is essential to prevent reinfestation.

Quality and grading of pistachios

Size and appearance are the most important components of pistachio quality. Defects that result in downgrading can be external, the shell, and internal, the kernel. External shell defects include total or partial non-splitting, adhering hull material, stained shells and damage by other means, including deformity and bird damage. Internal kernel defects include damage from insects and fungal pathogens, small immature kernels, rancidity and decay. Size, designated by the number of nuts per ounce (28 grams) is also an important quality attribute.

Grower payout is calculated from the fresh weight of pistachios delivered to the processing plant, corrected for the weight of foreign material removed prior to hulling. Prior to hulling, a grading sample is drawn from each delivery. This sample is processed individually, the fresh to dry weight ratio calculated, and third party inspected for the percentage by weight of split nuts, non-split nuts, blank nuts, nuts with adhering hulls, light and dark stain, and other defects. Correction factors for these defects, and for hulling and drying, are applied to the corrected delivery weight to calculate grower price. The major components in determining return to the grower are weight delivered, and the percentages by weight of the filled split, filled non-split and blank nuts.

Chemical composition and nutritive value

The approximate chemical composition of pistachios is given in Table 2. Actual composition may vary depending upon cultivar, maturity at harvest, and moisture content. After appearance, flavor is the most important aspect of pistachio quality. Thus far, production area within California and the presence of shell staining do not appear to have any effect on the flavor of pistachios. Maturity at harvest, moisture content (4 to 6% is optimum range) and total sugar content do influence flavor.

Table 2. Pistachio composition and nutritive value

Component (unit)	Amount per 100g edible portion
Water (%)	5.6
Proteins (%)	19.6
Fats (%)	53.2
Carbohydrates (%)	19.0
Fiber (%)	2.2
Ash (%)	3.0
Sugars (%)	6.1
Calories	594
Unsaturated/saturated Fatty Acids Ratio	8.1
Vitamins:	
A (I. U.)	230
Thiamin (mg)	0.67
Niacin (mg)	1.4
Vitamin C (mg)	0
Minerals: (mg)	
Ca	131
p	500
Fe	7.3
K	972
Mg	158

Summary checklist for harvesting pistachios

May: Establish contract with harvester, hauler and processor.
Selection of method of harvest and hauling in bin or bulk will depend upon distance to processor .

July: Make sure irrigation is up to 100% of tree need.

August: Start monitoring for early splits and third flight of NOW.

September: Begin monitoring nuts for color change and easy dehiscence of hull.