27

The Raisin Drying Process

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PRINCIPLES OF FRUIT DEHYDRATION

The outer layers and surface of grape berries have physical and chemical mechanisms to resist water loss—nature's way of keeping the berry hydrated and turgid. The principal barrier is the berry cuticle, which includes the outer layer of epicuticular wax or *bloom*. This wax consists of partially overlapping flat platelets that are irregular or lacelike in texture (Figure 27.1). Their orderly spacing and arrangement and the chemical characteristics of the wax provide water repellence and vapor loss resistance.

During drying, water in the grape berry moves in the liquid phase through the cells to the cuticle. It must then pass as vapor through the wax platelets and evaporate from the outside surface (Figure 27.2). Water movement within the grape is speedy in comparison to the slow transfer of water through the cuticle. The rate of water loss from the berry is dependent on the water's rate of transfer and availability at the berry surface. The transfer rate is governed by differences between the vapor pressure of the fruit and that of the surrounding air, referred to as *vapor pressure deficit* or *evaporative potential*. Vapor pressure deficits are greatest with a high berry temperature and a low relative humidity. High air temperatures and rapid air movement contribute to low relative humidities. Of these factors, berry temperature is the most important driving force in field drying.

Figure 27.1 Scanning electron micrograph of the 'Thompson Seedless' berry surface showing the typical arrangement and appearance of the cuticular wax platelets. *Courtesy of Dr. Birgit Uhlig.*

VARIETAL DIFFERENCES IN DRYING

The length of time raisins take to dry is governed by the physical characteristics of the grapes as well as environmental conditions. Studies have demonstrated that larger berries and thicker fruit skin both increase the drying time. This explains the differences between 'Zante Currant' ('Black Corinth'), 'Thompson Seed-

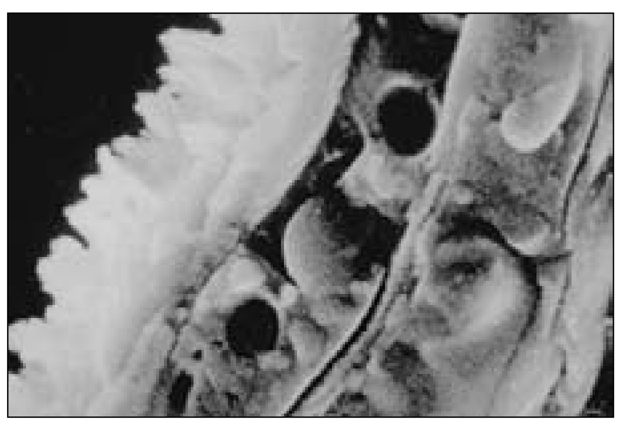

Figure 27.2 Scanning electron micrograph of a fracture through a frozen hydrated cuticle and epidermis of a 'Thompson Seedless' berry. The upper white layer is the epicuticular wax that is underlain by the cuticle and the cells with their wall structures.
Courtesy of Dr. Birgit Uhlig.

less,' and 'Muscat of Alexandria,' which rank from low to high in drying time, berry size, and skin thickness. Typically, 'Zante Currant' ('Black Corinth'), 'Thompson Seedless,' and 'Muscat of Alexandria' naturally sun dry in 7 to 10, 14 to 21, and 24 to 30 days, respectively. Drying time for 'Thompson Seedless' is longer when berries are enlarged through the use of gibberellic acid (GA) or by other means. Dehydrator studies with undipped fruit demonstrated drying times of 60 hours for 'Muscat of Alexandria' and 41 hours for 'Thompson Seedless.' This difference was calculated to be almost exactly inverse to the grapes' difference in surface area.

There are also differences among varieties of similar berry size. For example, 'Fiesta' dries more quickly than 'Thompson Seedless.' This was demonstrated in a 1995 replicated trial where 'Fiesta' and 'Thompson Seedless' were harvested on September 1 at the same soluble solids content (approximately 19.5 °Brix) and tray-dried to similar moisture contents. 'Fiesta' dried to 12.9 percent moisture when rolled on September 21, while 'Thompson Seedless' was at 13.3 percent moisture on September 25. Drying temperatures were normal during this 4-day period of difference. These data suggest that varietal differences in berry skin and cuticle characteristics also influence fruit drying rate.

TEMPERATURE CONDITIONS DURING FIELD DRYING

The normal (historical) average daily maximum and minimum temperatures recorded by the National Weather Service Station in Fresno during the raisin drying period are given in Figure 27.3. It shows the steady decline in average temperatures, equivalent to 1°F (approximately 0.5°C) about every 4 days, from mid-August to mid-October. Obviously, grapes harvested in mid-August are exposed to higher temperatures than grapes harvested several weeks later. Shorter days and lower sun angles also contribute to slowed drying later in the season. As a result, grapes harvested on August 25 typically dry within 2 weeks while those harvested 10 days later will take 2½ to 3 weeks.

Tray Drying Temperatures

Official weather reports give temperature readings from sheltered thermometers that represent ambient air temperatures. Temperatures on the raisin-drying trays, however, get much hotter. Representative tray temperatures during three different days of drying are depicted in Figure 27.4. The values show diurnal changes in berry temperature in the first, seventh, and fourteenth days of drying. In this study conducted

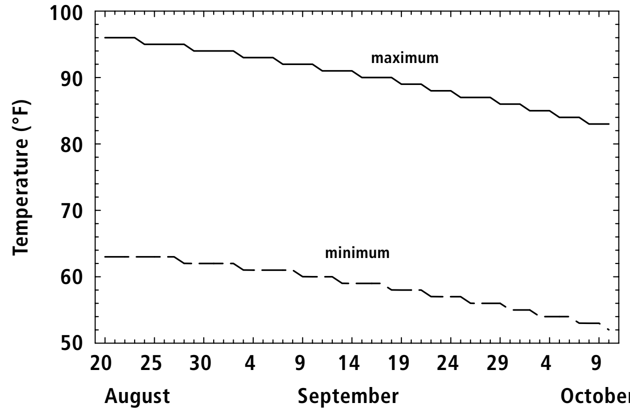

Figure 27.3 Normal (historical average) maximum and minimum temperatures during the raisin drying period, Fresno Air Teminal, U. S. Dept. of Commerce National Weather Service

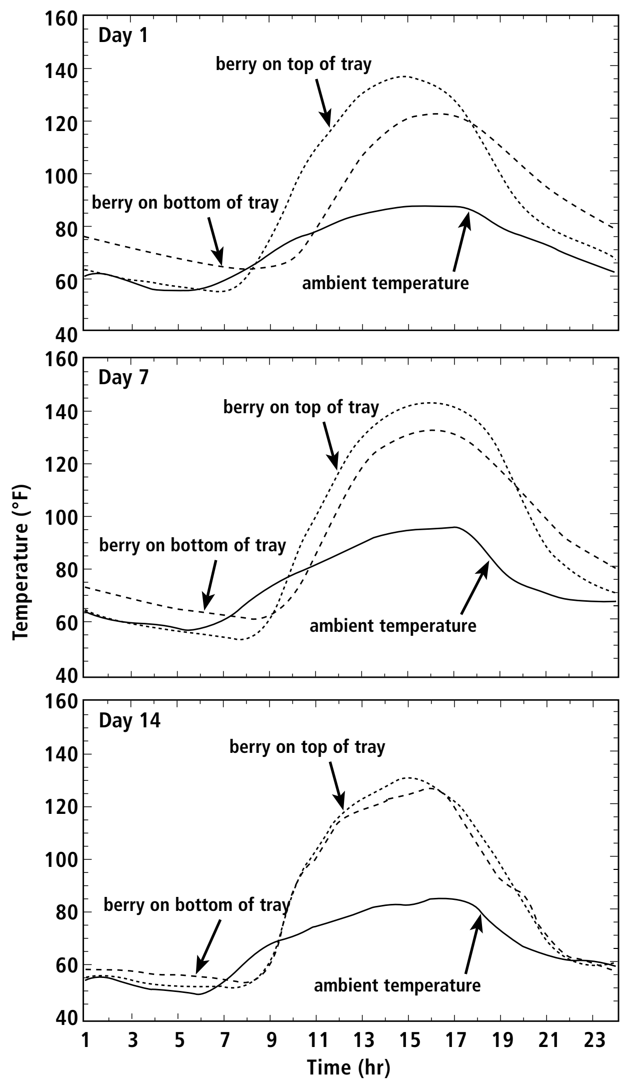

Figure 27.4 Raisin tray temperatures (°F) during days 1, 7, and 14 after harvest; hourly readings for 24-hour periods. Comparison of top and bottom berries on a tray with ambient temperature at a 5-foot (1.5 m) height. Kearney Agricultural Center, 1994.

at the University of California's Kearney Agricultural Center in Parlier, temperatures were recorded every hour as ambient in the row middle at a 5-foot (1.52 m) height and in berries on trays. Temperature probes were placed in berries at the top and bottom of the clusters on the trays. On day 1 maximum ambient temperature reached 87°F (30.8°C) in midafternoon, while berries on the top of the tray reached a peak of 136°F (58.2°C) several hours earlier. Berries on the bottom of the tray reached their peak temperature of 122°F (50.4°C) 3 hours after the top berries. The more exposed top berries cooled more quickly in the evening and dropped to ambient temperature by early morning. Day 7 was hotter, reaching 95°F (35.3°C) ambient temperature and 143°F (62.2°C) in the top berries. Initial differences between the top and bottom berries diminished due to the lower moisture content of the fruit. On day 14 the differences between the top and bottom berries were quite small, both day and night, due to their more similar exposure and moisture content.

These high drying temperatures are achieved by the absorption of radiant sunlight and heat accumulation at the soil and fruit surfaces during the day. The rise in temperature of berries on the top of the tray begins abruptly between 8:30 and 9:00 AM, rises rapidly until 12:00 noon, peaks about 3:00 PM, and then declines to near ambient temperature at about midnight. Berry temperatures above 150°F (66.1°C) have been recorded in other studies when ambient temperatures have reached 106°F (41.4°C). Such temperatures can contribute to sugar caramelization as discussed later in this chapter.

In-Row Distance Effects

Raisin trays placed at the row ends dry more slowly that those farther down the row. This is because the row canopies reduce air circulation, increasing both air temperature and humidity. The progressive increase in air temperature from the row ends toward the interior has been characterized in raisin drying studies as shown in Figure 27.5. It shows that ambient air temperatures and humidities increase with distance down the row beginning at about 10 AM. The differences reach a maximum from about 3 to 5 PM.

The differing rates of drying at these distances down the row are shown in Figure 27.6. It the study, the end trays always lagged behind those that dried at the higher temperatures 25 and 50 feet (7.5 and 15 m) down the row. The trays at 50 feet (15 m) were rolled 4 days earlier than those at the end; those at 25 feet (7.5 m) were rolled 2 days earlier than the end trays. These data confirm grower experiences of slower drying rates for end trays, and demonstrate the importance of temperature to the process. The higher temperatures down

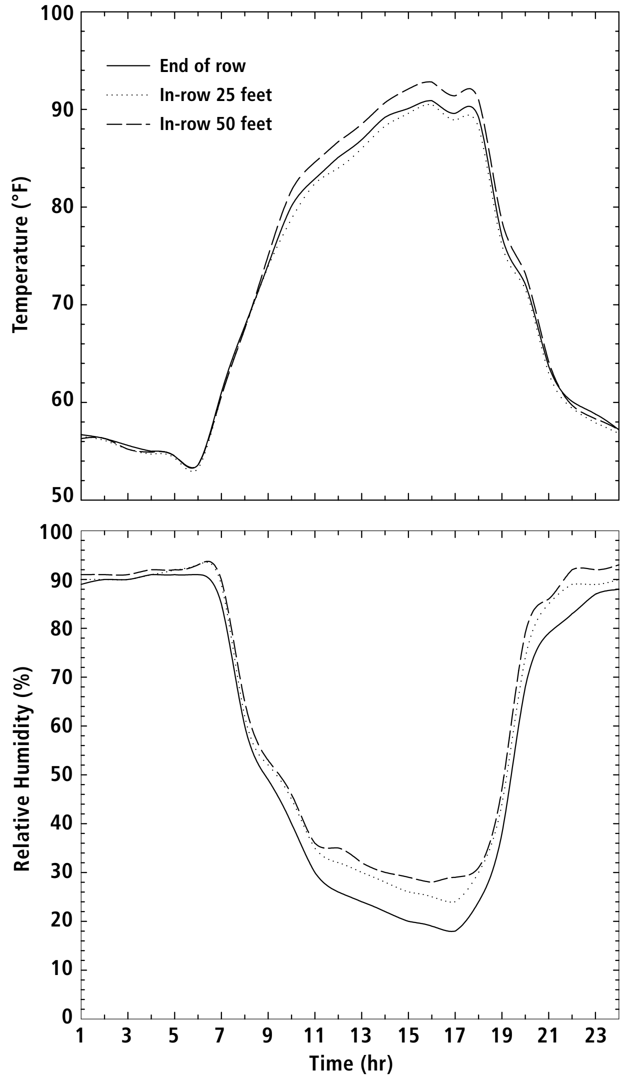

Figure 27.5 Ambient air temperatures (°F) and relative humidities (%) at a 5-foot (1.5 m) height during raisin drying. Comparison of distances of 0, 25, and 50 feet (0, 7.5, and 15 m) down a vineyard row; hourly readings over 24 hours. Kearney Agricultural Center, 1994.

the vine rows hastened raisin drying even though relative humidities were higher.

RAISIN TRAY CHARACTERISTICS

Tray Filling

Tray filling practices and tray types also influence drying rates. Most growers wish to fill trays with about 20 pounds (9 kg) of fruit as a compromise between reasonable picking costs and optimum drying. Figure 27.7 represents drying rates on trays filled with different amounts of fruit. The lighter trays dried more quickly, allowing for earlier rolling. Differences among the 16-, 18-, and 20-pound (7.3, 8.2, and 9.1 kg) trays were

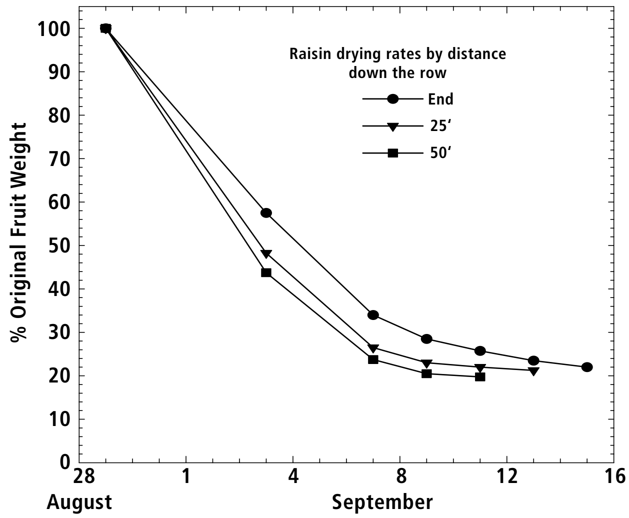

Figure 27.6 Drying rates (percentage of original fruit weight on trays at harvest) on trays located at 0, 25, and 50 feet (0, 7.5, and 15 m) down a vineyard row. Drying completed and raisins rolled on September 11 (50 feet), 13 (25 feet) and 15 (0 feet). Kearney Agricultural Center, 1994.

minor, 1 day at most. The 22-pound (10 kg) trays were typically 1 to 2 days behind the others, presumably because of a thicker fruit mass and less individual berry exposure on the trays. These differences are accentuated under poor (cool or humid) drying conditions. Lighter trays would be less risky for late harvests.

Tray Type

Drying options have increased with the availability of trays with different dimensions, coatings, and other paper treatments. However, differences in drying rate attributable to tray type on open trays are minor. This was demonstrated in a study that compared standard wet strength in two dimensions (24-×-36-inch standard and 26-×-34.5-inch extra wide), poly-coated (with and without venting), and extra wide with surface sizing (for descriptions of raisin tray types, see chapter 26, Harvesting and Handling. The results in Figure 27.8 show very minor differences in drying rates among tray types over 16 days. Moisture differences in the 4 days before rolling (Figure 27.9) show that raisins on poly-coated trays had the highest moisture content while poly-vented and extra wide were lowest. However, differences represented no more than one day of drying or 1.6 percent moisture at rolling on September 21.

Roll Type

Tray rolling slows the drying process and protects against rain. The rate of drying thereafter is influenced by type of roll (flop, cigarette, or biscuit) and whether the tray has a moisture barrier treatment. Biscuit rolls dry the slowest while cigarette and flop rolls are about equal in continued drying. Poly coating provides a barrier to moisture passing into or out of the roll. Moisture transfer is especially slowed when poly-coated trays are biscuit rolled. Poly-coated trays with vent holes provide for some moisture transfer from rolls.

The effects of roll type (flop, cigarette, or biscuit) and tray type (standard wet strength, poly-coated, or poly-vented) on the rate of raisin drying are graphed in Figure 27.10. Fruit on open trays continued to lose moisture rapidly, while moisture loss was slowest for the biscuit rolls, especially with poly-coated trays. Fruit in flop and cigarette rolls dried at similar rates and demonstrated rapid continued drying even in poly-coated trays. Moisture loss nearly stops when raisins on poly-coated or poly-vented trays are biscuit rolled. Obviously, poly-coated trays should not be biscuit rolled until the raisins have dried to at most 16 percent moisture.

DOV RAISIN DRYING

Raisins dry much more slowly on the vine than on trays since temperatures on the vine are much lower than on the ground. Temperature differences over 24 hours between ambient air, the tray surface, and north and south sides of the canopy in the fruiting zone are given in Figure 27.11. The tray was always warmer, and quickly increased in temperature from 70°F (21.3°C) at 8 AM to 146°F (63.8°C) at 3 PM. The south side of the canopy was next warmest, but only achieved a maximum temperature of 106°F (41.4°C). The north

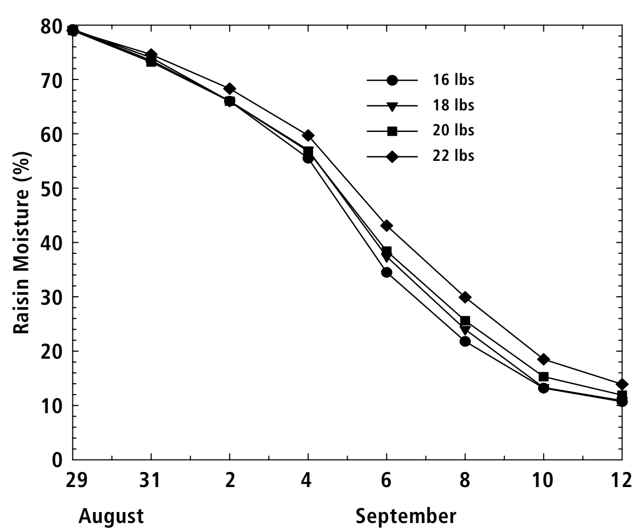

Figure 27.7 Drying rates (fruit moisture percentage) on trays filled with varying quantities of fruit: 16, 18, 20, and 22 pounds (7.3, 8.2, 9.1, and 10 kg). Data points represent the mean of eight replicate trays per treatment. Kearney Agricultural Center, 1994.

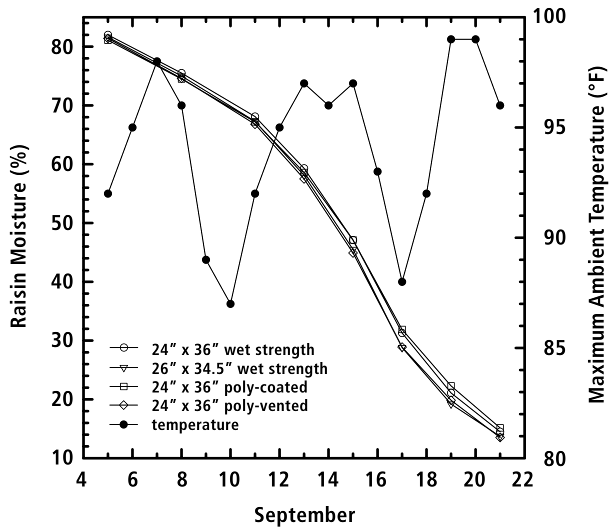

Figure 27.8 Daily maximum ambient air temperature (°F) 5 feet (1.5 m) above the terrace and drying rates (percentage of fruit moisture) on five different tray types. Data points represent the mean of six replicate trays per treatment. Kearney Agricultural Center, 1995.

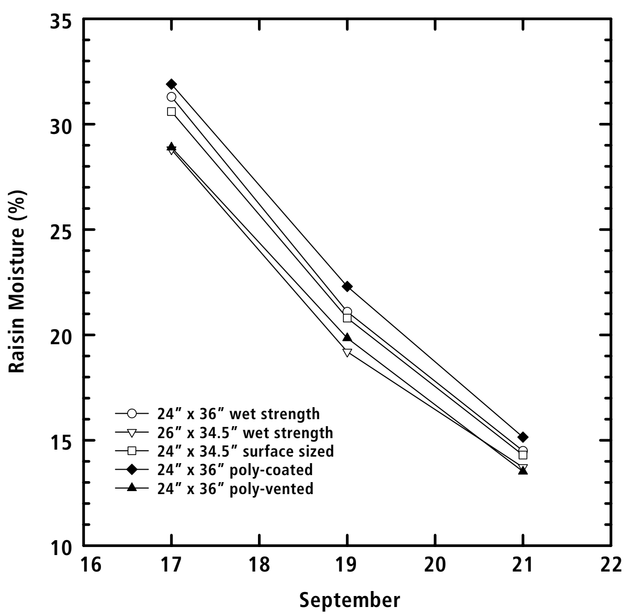

Figure 27.9 Last 5 days of drying data from Figure 27.6; percentage raisin moisture, September 17 to 21, 1995.

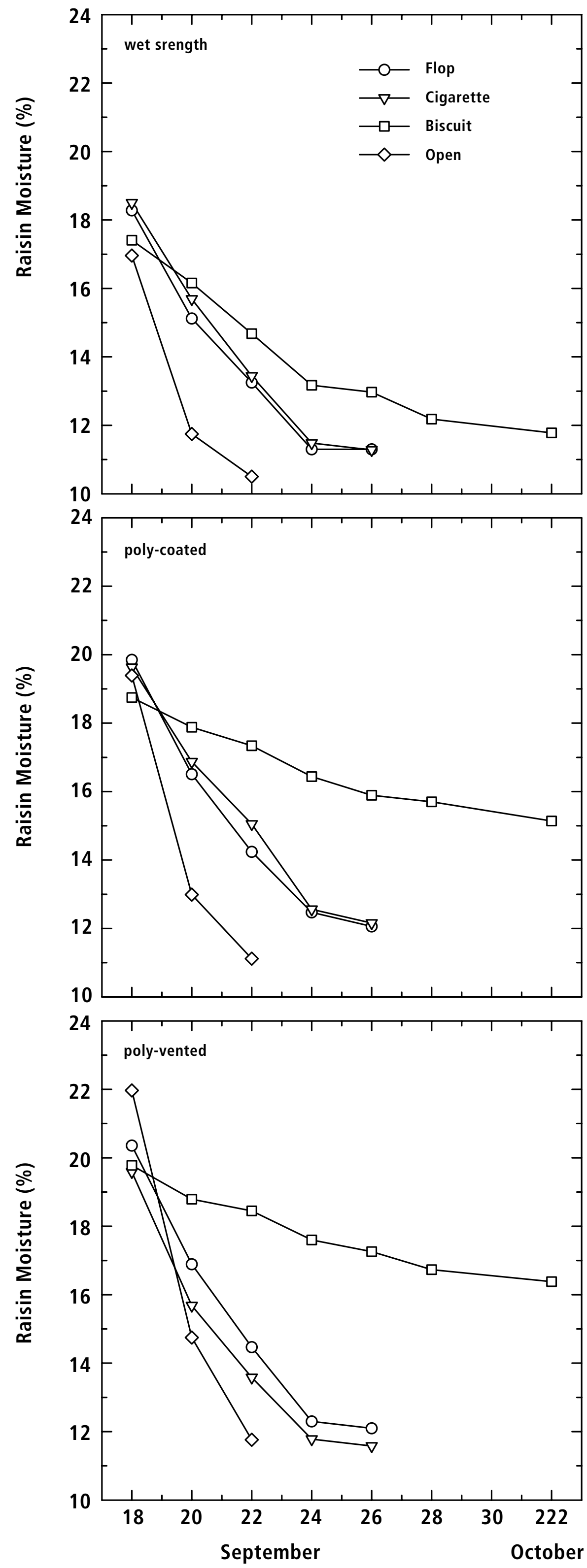

Figure 27.10 Raisin drying rates (percentage raisin moisture) on three tray types (wet strength, poly-coated, and poly-vented) after rolling in three roll types (flop, cigarette, and biscuit), plus an open tray comparison. Data points represent the mean of five replicate trays per treatment. Kearney Agricultural Center, 1995.

side was always coolest during the day, reaching 101°F (38.6°C) compared to a maximum 104°F (40.3°C) ambient temperature.

Trellis design and canopy configuration also affect temperature in the fruit zone and, therefore, DOV raisin drying rates. DOV drying rates in different canopies are given in Figure 27.12. An undivided canopy on a T trellis was compared with the south and north sides of the Australian Shaw trellis at the Kearney Agricultural Center in two successive drying seasons. Differences were not great in 1992, a hot drying season, as all treatments achieved acceptable raisin moisture 56 days after cane cutting. In the cooler 1993 drying season, however, there were wide differences, especially between the south and north sides which had 18 and 36.5 percent moisture fruit, respectively, at 68 days. The undivided canopy, which more closely approximates ambient conditions, was a little slower than south side, with 20 percent raisin moisture at 68 days.

DOV trellis systems designed for south-side drying (such as the Sun-Maid system) take advantage of the higher temperature and faster drying that occur on the south side. Systems with near-ambient fruit zone temperatures, such as overhead trellising, will require earlier cane cutting for 'Thompson Seedless' or the selection of an earlier-ripening variety such as 'Fiesta' or 'DOVine.' The use of north-south rows may be of benefit when fruit are exposed on both sides of the canopy.

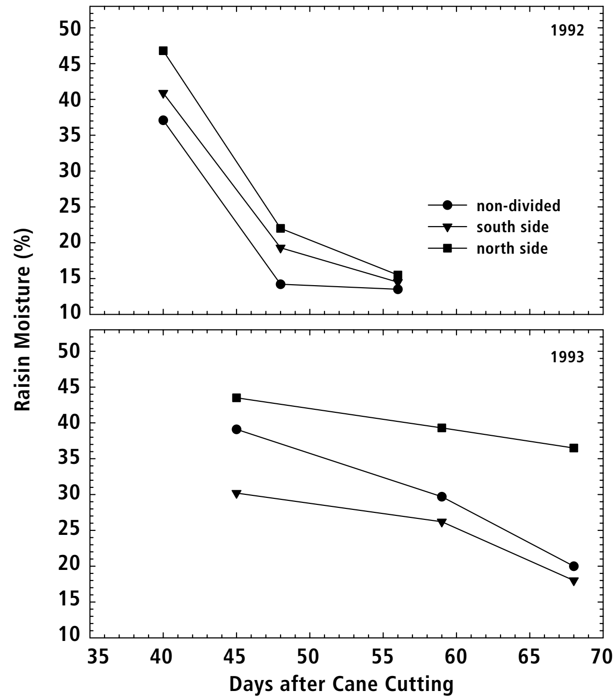

Figure 27.12 Drying rates of 'Thompson Seedless' DOV raisins in three canopy environments: non-divided with a T trellis and north and south sides of a Shaw trellis. Percent raisin moisture at various numbers of days after canes were cut August 14, 1992, and August 20, 1993. Data points represent the mean of three replicates per treatment. Kearney Agricultural Center.

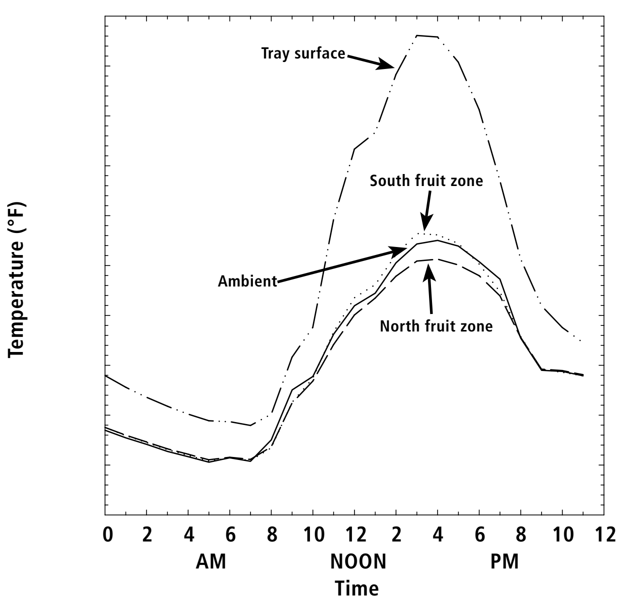

Figure 27.11 Comparison of temperatures (°F) in fruit drying on a tray, fruit in the north and south sides of a 'cross' DOV trellis, and ambient air 5 feet (1.5 m) above the vineyard floor. One-hour readings over 24 hours on September 9, 1997; canes cut on August 16. Kearney Agricultural Center.

In Australia, 'Thompson Seedless' DOV practices include spraying the fruit with a drying emulsion at the time of cane cutting. This speeds the drying rate considerably, enabling machine harvest of dried fruit after 2 to 3 weeks. It produces a light colored product which is marketed as a 'Sultana'-type raisin.

DRYING AIDS

Drying Emulsion Cold Dip

To accelerate raisin drying, fruit dipping mixtures were developed in ancient times in the Mediterranean area and Asia Minor. Initially, they were formulated using olive oil and wood ash. In modern times, wood ash was replaced with food-grade potassium carbonate (K_2CO_3), and the olive oil by specially formulated dipping oils. Today, most commercial cold dips utilize a combination of potassium carbonate and ethyl esters of fatty acids (commonly referred to as ethyl oleate) as active constituents in unheated water—hence the term *cold dip*. This treatment increases the rate of water loss twofold to threefold, an important factor in countries where drying conditions are very unpredictable. The shortened drying time is also important in achieving the desired light-gold fruit in 'Sultana' production areas such as Australia. Some countries such as Turkey and Greece still use olive oil extensively because it is relatively inexpensive and plentiful. The relatively high proportion of oleic acid in olive oil accounts for the similarities in activity of traditional and newer oil derivatives.

Drying Emulsion Use and Research in Australia

Much of what we know about drying aids comes from Australian experience and research. CSIRO (Commonwealth Scientific and Industrial Research Organization) researchers have evaluated many combinations of oils or fatty acids and alkaline salts. Overall, they have found that both constituents produce a synergistic reaction to modify the berry cuticle—a reaction that cannot be achieved fully with either one alone. While the exact role of the constituents of the emulsion are not fully understood, present knowledge indicates that the fatty acids mainly modify the outer wax layer while the potash (K_2CO_3) neutralizes free acids and their electrical charges in the cuticular membrane.

The fatty acids change the primary structure and arrangement of the wax platelets and reduce their surface tension. Upon penetration, they interact with the soluble waxes and establish a hydrophilic (water-conducting) link between the berry surface and the water-containing parenchyma cells. They also cause the waxy layers to swell, pushing them apart. This creates a water continuum through the cuticular membrane—a water path from the saturated interior to the berry surface—thus facilitating the flow and transpiration of water.

K_2CO_3 neutralizes any free acids present in or on the skin, including those of the wax, converting them into their potassium salt. Absorption of water would also be aided by the neutralization of fixed charges with K^+. CO_3 also stabilizes the emulsion by increasing pH.

The relative effectiveness of the emulsion constituents presently used and the rates used by industry are summarized below:

Oil: Unsaturated fatty acids, including oleic acid ethyl ester are most effective, probably because of their molecular structure and bonding, which enable them to penetrate into the cuticle and alter the arrangement of the wax components. Saturated fatty acids are less effective.

Alkali salt: Potassium (K^+) is one of the most effective cations, presumably because of its smaller ion radius when hydrated (combined with water), as compared to that of sodium, lithium, or calcium. Carbonate ($CO_3^{=}$) is more effective than other anions, including chloride and hydroxide.

Rates: The original fruit dipping solutions consisted of 2.5 percent K_2CO_3 (by weight) and 2 percent ethyl oleate (by volume); now commercial recommendations have been reduced to 2.0 percent K_2CO_3 and 1.6 percent ethyl oleate. If spraying onto rack-dried fruit, as is the practice in Australia, lower-strength formulations of 1.25 percent K_2CO_3 and 1.0 percent ethyl oleate are used. For DOV, 0.6 percent K_2CO_3 and 0.5 percent ethyl oleate have proven satisfactory in Australia.

Drying Emulsion Use and Research in California

Interest in the use of drying emulsions in California during the 1970s to mid-1980s was prompted by the potential of DOV to help mechanize harvest and to minimize losses from rain during tray drying. Research by California State University, Fresno and USDA Agriculture Research Service personnel during the period largely confirmed experience reported from Australia with regard to emulsion formulation. The Australian DOV practice of cutting canes and spraying fruit with the emulsion was evaluated, and some commercial lots were produced. However, vine yields went down over time as a result of cane cutting and damage to the remaining canopy from the application of emulsion. Also, the market for the treated raisins, which had different appearance and flavor characteristics, was very limited and not economically favorable.

The spray-on-tray (SOT) treatment with the emulsion was also developed by CSU Fresno researchers as a means to shorten drying time and thus rain risk. Once the grapes were spread on the trays they were sprayed with emulsion from a tractor straddling an elevated terrace. Recommended rates were 2 percent ethyl oleate (by volume) and 2 percent K_2CO_3 (by weight). Drying rates were increased 30 to 50 percent with this practice, provided the application was made within 2 days of harvest. There was little or no advantage in a second spray after tray turning. By 1984, 7,745 tons of raisins were produced with this method. It was largely abandoned by 1988 due to the added production costs and absence of premium prices for SOT raisins.

Today drying emulsions have limited use in California, but they may be useful in the future. They may have a place in California DOV practice, especially at the low application rates. Also, cold dips (ethyl oleate + K_2CO_3) can be used in tunnel dehydration rather than the hot, caustic soda dip in current use. While the cold dip may take several more hours to tunnel dry, it produces a less sticky and more free-flowing product than the hot dips.

California Hot Dips

Hot dips are all used in conjunction with tunnel dehydration. Soda dip is the treatment (immersion or spray) of grapes for 8 to 15 seconds with a caustic soda solution (0.2 percent to 0.5 percent sodium hydroxide by weight) heated to about 180°F (82°C), followed by a cool water rinse. This checks the skin, producing cracks and openings in the epidermis to facilitate transpiration. Some of the cuticle is also dissolved and altered to hasten water loss. This dip treatment is primarily used in the production of light colored "golden seedless" raisins. Grapes for golden seedless also receive sulfur dioxide (SO_2) treatment in sulfur houses after they are dipped, spread on trays, and stacked onto rail cars. Tunnel drying time for golden seedless is about 28 to 32 hours at about 150°F (65°C) temperature at the intake (hot) end.

There is a trend among dehydrator operators toward using less caustic soda along with water temperatures above 200°F (93°C). This is because caustic soda treatment tends to produce more variable results depending on fruit temperature and maturity. "Over-checking" of some berries contributes to more stickiness and variability in fruit color. Dipping at a high water temperature with caustic soda rates below 0.25 percent contributes to greater uniformity in fruit checking. Some golden seedless raisins are produced with hot water dip only, as described below.

The hot water dip has totally replaced the soda dip for the production of tunnel-dried, dark-colored raisins. No dipping chemicals are used. This treatment produces a dark, *dipped seedless* raisin that competes in the *natural seedless* market channels. The fruit is dipped for 8 to 15 seconds in a 190° to 210°F (88° to 99°C) hot water bath to check the skin. Raisin dehydration to 10 or 13 percent moisture is completed in about 28 hours in a 14-car tunnel at 160° to 180°F (71° to 82°C) at the hot end. Shorter tunnels (10 to 12 cars) and high-maturity fruit will take 20 to 24 hours to dry.

COLOR CHANGES DURING DRYING

Browning is caused by *enzymatic* and *nonenzymatic* browning reactions initiated through cell breakdown from cell dehydration. The predominant enzymatic browning occurs when polyphenol oxidase (PPO) comes into contact with phenolic compounds (principally caftaric acid in grapes) when cell integrity is lost. Polyphenol oxidase is a generic term for the group of enzymes that catalyze the oxidation of phenolic compounds to produce brown color in exposed or disrupted plant tissues. The brown color results from the formation of quinones, which undergo oxidative polymerization to produce brown-black melanin pigments. Oxygen (O_2) and water must be present if the reaction is to take place. Most of the PPO activity is found in plastids, including chloroplasts, in the skin and in the seeds or seed traces. Thus, browning begins at the periphery and center of the berry, but rapidly progresses throughout the pulp as the substances come into contact with one another. Nonenzymatic browning, known as the *Maillard reaction,* is a much slower process caused by a reaction of reducing sugars with protein amino groups.

Influence of Drying Conditions

Browning is increased with higher temperatures and slower drying; rapid drying at cooler temperatures concentrates sugars that inhibit PPO activity and tends to maintain more cellular integrity. Thus the relatively slow field tray-drying of undipped fruit at high temperatures produces the dark colored *natural* raisin. Conversely, raisin industries elsewhere, as in Australia, strive for uniformly light colored raisins for their 'Sultana' market. Light coloration is optimized by cold dipping to speed drying and rack drying at ambient air temperatures. Some 'Sultanas' retain an objectionable green tinge after drying. The problem is greatest with low-maturity fruit and clusters that ripen in a shaded part of the canopy, thus retaining more chlorophyll. Emulsion-dipped fruit dried in the shade also tends to retain more chlorophyll and thus green color. Fruit dried in the dark remain even more green and lighter in color than shade-dried fruit. *Green naturals* produced in Afghanistan and China retain much of their original green-golden color due to the tradition of drying in dark, vented drying houses.

Sulfur Dioxide Use

California golden seedless raisins retain their light color because of sulfur dioxide (SO_2) treatment after dipping and before dehydration. It retards both enzymatic and nonenzymatic browning, preserves the natural flavor, and retards the loss of pro-vitamin A and ascorbic acid. Sulfur dioxide is a reducing agent that prevents the enzymatic conversion of the phenolic compounds. Sulfur dioxide gas is injected into sulfur houses from pressurized tanks to achieve a total rate of about 5 to 8 pounds per ton of fruit. The fruit is left in the house for 5 to 8 hours to absorb the SO_2. Traditionally, the goal was to achieve an SO_2 concentration high enough to give the processed fruit a minimum of 2,000 ppm for golden color retention through distribution and marketing. However, some markets such as the European Economic Community and Japan will not accept dried fruit containing more than 2,000 ppm SO_2. Dehydrator operators may have to decrease dosages or modify practices to meet these requirements in the future.

Other Treatments

Other processes or products are known to prevent or retard browning. Polyphenol oxidase-catalyzed browning can be prevented by heat inactivation of the enzyme, exclusion of a substrate such as oxygen, lowering fruit pH, or using other reducing agents (antioxidants) such as ascorbic acid. Heating the fruit to 190° to 208°F (88° to 98°C) for 2 to 3 minutes has been shown to deactivate the enzyme, allowing light colored dehydrator fruit. However, the fruit will gradually darken in storage without SO_2 treatment. Exclusion of O_2 has been accomplished experimentally with microwave-vacuum drying in a liquid media or air drying in an oxygen-free chamber. Ascorbates, erythorbates, and sulfites such as sodium metabisulfite are also important antioxidants used to prevent browning in numerous fruit products. Potassium sorbate (Monsanto MP-11) is a food-grade mold inhibitor that has been used successfully as a prerain spray on tray-dried fruit. Its antioxidant properties produce a lighter, more reddish raisin that is categorized as *oleate* for market pooling. Some foreign 'Sultana' producers also add metabisulfite solution during processing for retention of light color in the package.

There is continuing interest in the employment of new methods to produce light colored fruit without SO_2-producing treatments such as SO_2 gas and metabisulfite, a response both to the off flavor associated with this treatment and concern about reactions associated with certain types of asthma. A 'Thompson Seedless' *sport* (mutation) called 'Sultanina Marble' produces lighter colored fruit because of the low chlorophyll content of its berry skin, and a correspondingly low PPO content. A grape variety genetically engineered to produce no PPO would be ideal for producing consistently light colored raisins without chemical treatment. The Australian CSIRO research organization has now developed and patented such a variety.

SUGAR CARAMELIZATION

At high temperatures, grape sugars are altered to produce a burnt or "caramelized" flavor as well as a darkened appearance. The reaction accelerates as the raisins dry below 13 percent moisture, and occurs most commonly at the end of tray drying at high fruit temperatures above 140°F (60.5°C). Gases produced from sugar degradation can also give raisins a burnt and puffed-up ("puff-ball") appearance. This is more of a problem with the 'Fiesta' variety. Dehydrator operators will usually maintain the temperature of the intake (hot) end of the tunnel at or below 165°F (74.5°C) to avoid caramelization.

RAISIN SUGARING OR CRYSTAL FORMATION

Sugaring is a physical-chemical disorder of raisins that mostly occurs during prolonged storage. It appears as a white to yellowish brown crystalline material on the raisin surface, and detracts from the raisins' appearance and eating quality. Internal crystals can also develop in some raisins. External sugaring usually first appears on the ridges of raisin wrinkles, presumably because the skin's greater permeability in this area allows the migration of soluble solids to the exterior. Analyses of the deposits have shown that they consist primarily of the grape sugars, fructose and glucose, and tartaric acid. Traces of the amino acids lysine, asparagine, and aspartic acid, as well as malic and citric acid, may also be present.

The exact cause for this crystallization is not known. Nuclei for crystal development could include yeast and bacteria. As far as is known, field drying conditions such as temperature or duration do not influence sugaring. Fluctuating storage conditions such as temperature and humidity, especially at higher levels, are contributing factors. Packers report more problems in processed fruit, but the degree contributed by capstemming and processing and the higher moisture content is not known. Stemmed and unstemmed raisins of low moisture (9 to 11 percent) did not sugar during one year of storage tests, whereas all lots at 15 percent moisture and above were sugared. However, excessive handling and abrasion of raisins, as on a shaker or during reconditioning, and high moisture content are known to be important factors in sugaring. Also, high rates of nitrogen fertilization have been associated with increased sugaring.

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