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Tunnel Dehydration

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Raisin dehydration in heated air dryers was first devised in the early part of the twentieth century as a means of salvaging rain-damaged raisins. It was also used for a short period to preserve wine grapes during the Prohibition era after ratification of the Eighteenth Amendment. In 1925 the light colored golden bleached raisin was developed, and it required dehydration. Annual production of this new product was about 25,000 tons until World War II. During the war, dehydration was used extensively to ensure a stable supply of product.

Many of the earliest dehydrators had no fans and used natural draft to slowly move air past fruit placed on a slotted floor or through fruit placed on trays. In the early 1920s commercial dehydrator firms began marketing a number of types of forced-air dehydrators and these quickly became the industry standard. The main differences between the designs were the location of the air recirculation duct, the type of heating system, and the type of fan, but they operated in the same general fashion as the truck-in-tunnel dehydrators now in use (Figure 29.1).

Today, raisins dried in heated air dryers make up about 9 percent of the 380,000 tons of raisins produced in California in a typical year. In most years, the dehydrators mainly produce golden bleached raisins (about 20,000 tons per year) and there is often excess dehydrator capacity. In years when the sun-dried fruit has been rained on, the dehydrators are also used to dry reconditioned raisins. Reconditioning uses a water treatment to remove fruit with mold, insect damage, contamination detected through microscopic analysis, and imbedded sand. The good fruit that remains is dehydrated. Some companies produce a water-dipped raisin. Production of these dehydrated raisins over the past ten years has been about 13,000 tons per year. Its appearance is similar to that of a natural sun-dried raisin, but it may have a slightly lighter color.

Figure 29.1 Multiple-tunnel raisin dehydrator built of concrete block. *Photo: Jack Kelly Clark.*

Dehydrated raisins tend to have a lower dry-away ratio (mass of grapes required to produce a unit mass of dried raisins), a slightly higher airstream grade, and a higher sugar content, measured as the amount of reducing sugars compared with that of the sun-dried product. The reasons for these differences have not been determined.

Dehydration with a heated air dryer is significantly more expensive that sun drying. A 1988 study showed that returns to the grower for water-dipped raisins were $258 to $434 per acre less than for sun-dried raisins. Dehydration is cost effective only for specialty, high-valued products like sulfured raisins or reconditioned rain-damaged fruit when rain losses can cause fruit value to rise. Even considering the periodic losses associated with rain during the sun-drying period, dehydrated raisins are not cost competitive with sun-dried natural raisins. Heated air drying of raisins continues because the dryer operators always dry some golden bleached raisins and they want to make more use of their drying facilities. They can improve the economics of the process by buying fruit at winery prices, which are lower than that for sun-dried product, and they can buy fruit that is more mature later in the season and produce a better grade product and one with a lower dry-away ratio.

Grapes intended for dehydration are hand harvested and transported to the drying facility in pallet bins. Golden bleached raisins are dipped in a hot solution of water and sodium hydroxide to produce tiny cracks in the skin of the fruit in order to speed drying. The fruit is then placed on trays and exposed to gaseous sulfur dioxide. The water-dipped product is exposed to a brief hot water treatment before drying.

Nearly all California processors of this type of raisin use a convection-type, truck-in-tunnel dehydrator (Figure 29.2). Continuous-flow belt-type dehydrators have been used successfully to dry raisins and they have potential for faster drying and lower labor and energy costs, but these savings cannot offset their high capital cost during the short, 4- to 6-week drying season.

Tunnels are built using concrete block or tilt-up concrete construction methods. The fan is mounted in the air return channel above the drying chamber and a direct-fired natural gas or propane burner is installed near where fresh air enters the dryer.

Tray loading, removal of dried fruit from trays, and some pretreatment are done in a central facility near the dryer (Figure 29.3). The grapes are loaded on to 3-by-6-foot trays. Trays are made of lumber or plywood and built with three spacers to allow air to flow past each tray. Wheeled trucks hold 25 to 26 trays each and are used to move the tray stacks through the dryer and around the facility. The loading of undried grapes onto trays and the removal of dried product are semi-automated (Figure 29.4).

The dryer is operated in a more or less continuous flow, with a new carload of trays added to the dryer and a dried carload removed every 1½ to 2 hours. The direction of flow for these carloads of fruit is opposite the direction of air flow through the dryer (*counterflow operation*).

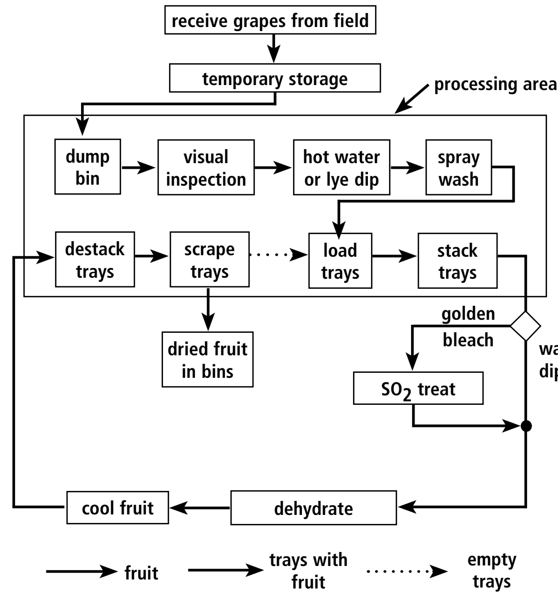

Figure 29.3 Schematic diagram of the fruit handling process in a dehydration facility

PRETREATMENT

Golden bleached raisins are dipped for 8 to 15 seconds in a 180°F (82°C) aqueous solution of 0.2 to 0.5 percent sodium hydroxide, and then rinsed immediately with cold water. The sodium hydroxide treatment causes small cracks in the fruit's skin which allow greater rates of water loss, hastening drying. The fruit is then spread on drying trays and taken to a chamber for sulfur dioxide (SO_2) treatment (Figure 29.5). In years past the SO_2 was produced by burning powdered sulfur. Today SO_2 gas comes from pressurized tanks. About 5 to 8 pounds of gas are used per ton of fruit, with an exposure time of 5 to 8 hours. This produces a fruit sulfur content of over 2,000 ppm (sulfite basis).

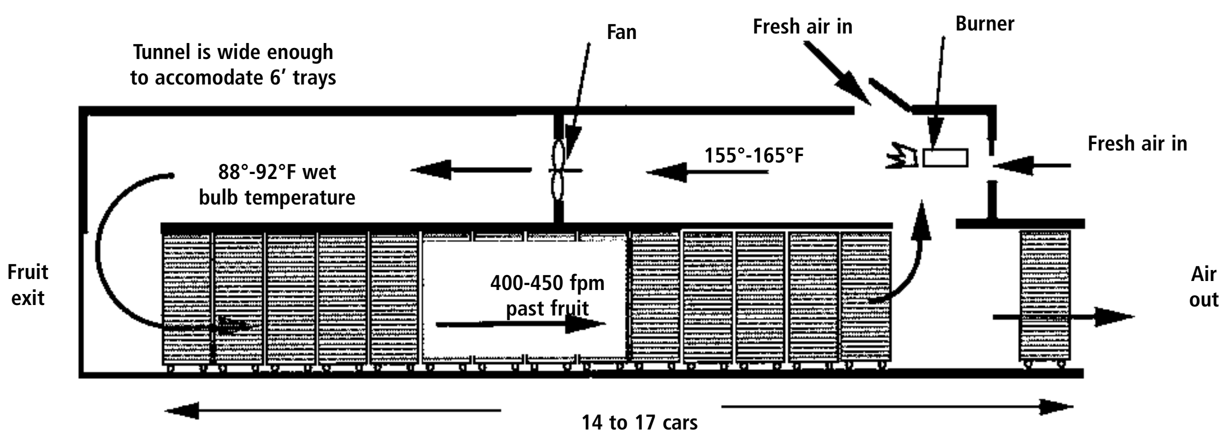

Figure 29.2 Schematic diagram of a convection-type, truck-in-tunnel dehydrator

Figure 29.4 Tray-scraping procedure. *Photo: Jack Kelly Clark.*

Grapes for water-dipped raisins are exposed to water at 190° to 210°F (88° to 99°C) for 8 to 15 seconds. This treatment speeds drying over that of untreated fruit, but results in a dark-colored raisin that is marketed as a water-dipped or "natural" raisin.

DEHYDRATOR OPERATING CONDITIONS

Air temperature. Hot end air temperature (dry bulb temperature) is limited to a range from 155° to 165°F. In the counter-flow system, the driest and consequently the hottest product is in contact with the highest-temperature air. Air temperatures above this range result in fruit temperatures high enough to caramelize sugars and produce an off flavor.

Concurrent-flow operation, where the fruit moves through the dryer in the same direction as the air, allows the use of higher air temperatures and faster drying at the beginning of the process. In this design the hottest air is in contact with the wettest fruit and

Figure 29.5 Trays of grapes being loaded into sulfuring chamber. *Photo: Jack Kelly Clark.*

the rapid loss of water from this fruit quickly cools the drying air to a temperature low enough to prevent caramelization of the nearly dried fruit at the far end of the tunnel. When prune dehydrators switched to concurrent-flow operation in the 1960s, they decreased drying time by about 30 percent. However, raisins are dried to a lower moisture than prunes: less than 14 percent wet basis, which corresponds to a water activity of less than 0.50. The raisins cannot reach this low moisture content quickly unless the most nearly dried fruit is in contact with the hottest, lowest-humidity air.

Air humidity. Humidity of the air in the dryer is measured as wet bulb temperature, the temperature of a thermometer covered with a wetted cotton wick. Higher wet bulb temperatures correspond to higher relative humidities and higher moisture ratios. Dryers are often operated with an 88° to 92°F wet bulb temperature. Increased air recirculation increases air humidity as measured by wet bulb temperature and reduces energy use. As wet bulb temperature approaches 100°F, air humidity becomes high enough to noticeably increase drying time. This limits the amount of air that can be recirculated.

You can also use electronic meters to measure air humidity, but they usually measure relative humidity, which is not consistent through out the tunnel. Air temperature also needs to be measured, and the two numbers used together to determine wet bulb temperature with the aid of a psychrometric chart.

Fruit loading on trays. Each 3-by-6-foot tray is loaded with about 70 pounds of grapes (3.9 lb per square foot). Approximately 4 pounds of undried fruit produce 1 pound of raisins (dry away ratio = 4.0), although the sugar content of the grapes affects this ratio. A high sugar content reduces the dry-away ratio.

Fruit moisture. Raisins are dried in the dryer to less than 14 percent wet basis moisture content. They often continue drying to 12 to 13 percent moisture in long-term storage. Moisture is measured with a specially designed dried fruit meter that correlates electrical resistance and fruit temperature with moisture content.

Air speed. Air speed past the fruit should be at least 400 to 450 feet per minute. Lower air speeds will slow the drying rate. Higher speeds increase the drying rate slightly, but at progressively increasing electricity costs for fan operation.

Energy use. One study showed that raisin dryers require 1,900 to 2,500 Btu of fuel input per pound of water evaporated. At normal atmospheric pressure, water requires about 1,000 Btu per pound for evaporation, so the water evaporation efficiency in this study ranged from 52 to 40 percent. The lower fuel use with higher efficiency was caused by increased air recirculation. Recirculation was increased by removing a car placed under the air recirculation opening in the dryer ceiling. It may also be controlled by adjusting the setting of the air supply doors on the roof and on the wall near the burner. To determine the best door setting for maximum air recirculation, first operate the tunnel with a normal, fairly open setting, and determine the drying time. Then, using similar batches of fruit, operate the tunnel several times, each time with the air intake doors progressively further closed. At some door setting, the fruit drying time will noticeably increase; the maximum setting is slightly more open than this. You can then measure the wet bulb air temperature at this maximum setting and use it as a guide to set the door positions in the future.

Solar collectors have been tried as a heat source, but have proven to be uneconomical. The most effective way to reduce fuel costs is to recirculate the maximum amount of drying air.

TUNNEL OPERATION

Drying time changes during the season and between fruit lots depending mainly on the sugar content of the incoming grapes. Operators check raisin moisture by squeezing a handful of fruit and checking its softness. This impression of the "feel" of dry fruit should be checked by using instruments to measure the moisture of several samples. Incompletely dried fruit can be left in the last one or two car positions for extra drying time, and the cycle time may need to be lengthened. If fruit on one car is too dry when it is removed, the next car may already be dry and ready to be removed. Reduce cycle times if the dehydrator consistently overdries fruit.

At the beginning of the drying season, start by operating the dryer with standard cycle times, using empty trays to fill empty positions in the dryer and a slightly lower than normal air temperature. As the tunnel becomes more filled with fruit, you can increase the air temperature. Cycle time is adjusted after the first few cars of fruit are removed from the dryer.

Most tunnels are operated continuously until the end of the season. As the volume of raisins diminishes toward the end of the season, fill the empty car positions again with empty trays to maintain consistent air flow. You have to check fruit moisture more frequently then, since the last few cars will require less drying time than they would under normal, full-dryer conditions.

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