PROGRESS REPORT ON PARALLEL- AND COUNTER-FLOW DEHYDRATION OF PRUNES

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Of an annual production of 165,000 tons dried prunes in California, practically all are dehydrated in tunnel dehydrators. While there are a number of designs, the most common dehydrator tunnel used for drying prunes is a ten car twin tunnel. It is operated in a counter-flow procedure, i.e. drying air is introduced into one end of the tunnel and moves in a direction opposite to that of the trayed fruit. This type of tunnel operation is characterized by having conditions most conducive to rapid drying at the end of the tunnel where the prunes are nearly dry. The maximum permissable air temperature, therefore, is that which the nearly-dried prunes will withstand for a period of several hours without incipient heat damage. The procedures for designing a counter-flow tunnel dehydrator were developed for most part by A.W. Christie, W.V. Cruess and P.B. Ridley of the University of California in the early 1920's. The design and operation of early prune drying tunnels were strongly influenced by the desire for heat economy. As late as 1948, recommendations of having the discharge air at 60% relative humidity were based on this desire. Observations in recent years of present day practices show that less importance is being placed on heat economy since many dehydrators are discharging air with a relative humidity of 25-30%. This has been done to increase the dehydrator capacity and output.

Many recommendations made in the past for prune dehydrators are no longer being followed since experience, trial-and-error modifications, and equipment changes have shown that they did not result in efficient dehydrator performance.

One of the early studies to determine the relation of air conditions to quality of the dried product was done in 1940-41 by Moses and Guillou. Since most of this work was done at fixed temperatures and humidities, the evaporative cooling of the fruit was not considered. This latter factor was shown by the work of Perry in 1944 who measured the temperature of the fruit when dehydrated at a constant temperature. Here, using a dry-bulb temperature of 167-170°, the actual fruit temperature was still 17° below the air temperature after four hours in the dehydrator.

In 1962 investigations were initiated to evaluate recent prune dehydrating processes, particularly with respect to improving dehydrator performance. The possibility of increasing the capacity of the tunnel by converting from counter-flow to parallel-flow operation was investigated. In contrast to counter-flow operation, parallel-flow dehydration has both fruit and air passing through the dehydrator in the same direction. It is characterized by very fast drying conditions in the portion of the tunnel where the product to be dried is still very wet. The effect of evaporative cooling, therefore, makes it possible to use a high initial temperature without heat damage to the product, thus making possible a higher drying capacity.

Data published by Christie in 1926 show the unsatisfactory attempts to dehydrate Imperial prunes by this method. The method was unsuccessful in that considerable cracking, bleeding and the loss of juice occurred. In addition, the dried fruit had an objectionable light reddish color.

The present report includes data collected during the 1963 season on French variety prunes from the northern coastal and from the Sacramento Valley areas. Fruits were harvested at early, mid- and late season. Fruit from the valley area were transported by truck to the dehydration plant in the northern coastal area.

Prior to dehydration the prune sample was divided into three sizes for evaluation purposes and trayed and stacked in selected locations on cars. A random sample collected prior to sizing was used as a "field-run" control sample. For each sample, sublots were placed in one twin tunnel dehydrator which had been modified so parallel-flow operations could be used. Duplicate sublots were placed in a similar tunnel operating in a conventional counter-flow manner. Air temperatures at the warmest portion of the tunnel were 195°F dry bulb for parallel-flow and the wet bulb was 115 ± 3°F. Counter-flow operations used a dry bulb of 165°F and the wet bulb temperature was 105 ± 3°F. The average air velocity in the tunnel was 800 feet per minute. Measurements ranged from 600 fpm to nearly 1200 fpm.

Table 1 shows the drying times and moisture contents of the sized prune samples. The average drying time in the parallel-flow tunnel was 14.26 hours compared to 19.65 hours in the counter-flow tunnel. This reduction in average drying time permits a 37% increase in dehydrator capacity.

The maintenance of the higher temperature in the parallel-flow operation increased the rate of fuel consumption to 26.55 cfm, whereas the counter-flow operated tunnel used fuel at a rate of 17.3 cfm. When calculated on a weight basis of fruit dried this difference represents a 12% increase in the fuel consumed for parallel-flow operation of a tunnel. Fruit characteristics of prunes dried in parallel- and counter-flow dehydrations are shown in Table 2. The results for fresh fruit and dried fruit show the samples were very similar for each size category with only minor variations observed.

Differences in drying ratios (lbs. pressure/lb. dried fruit at 20% moisture content) arise from the differences in the soluble solids content of the fresh fruit.

Differences in the color changes of the flesh between fresh and dried fruit were similar. Changes in the value, which represents the brightness of the color, and hue, or the actual color itself, between the parallel- and counter-flow drying procedures are shown in Table 2. The changes in hue were influenced to a small extent by the size of the fresh fruit, being greater for fruits of larger sizes. While external skin color was not measured initially, fruit dried by the parallel-flow procedure appeared visually to have more of a reddish cast than fruit dried by counter-flow dehydration. This difference was not apparent after several months of commercial storage.

From the data collected in the 1963 season, it appears as though fruit dried either by parallel- or counter-flow operations are similar in their characteristics. Fuel consumption is higher in parallel-flow operations, although the capacity is increased approximately 37% for average drying times. As noted in Table 1, size grading into two or three sizes of fresh fruit would appear to be of additional benefit since the drying time for sized fruit may permit more regular loading schedules.

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TABLE 1

Moisture content and drying time of sized prunes dried in parallel- and counter-flow tunnels.

		Parallel-flow		Counter-flow	
Size	Count/lb.	Drying time (hrs.)	Moisture (%)	Drying time (hrs.)	Moisture (%)
Large	37-47	16.25	20.6	23.25	20.1
Medium	48-60	14.83	19.9	20.67	19.75
Small	61-74	11.71	19.1	15.04	20.1
Average		14.26	19.9	19.65	20.0

TABLE 2

Fruit Characteristics of Prunes Dried in Parallel- and Counter-flow Tunnels.

Size	Dehydration Procedure	Fresh Fruit: Average Flesh Firmness (lbs.)	Fresh Fruit: Average Soluble Solids at 20°C (%)	Fresh Fruit: Average Count per lb.	Dry Fruit: Average Count per lb.	Drying Ratio	Color Differences* Fresh - Dry: Value	Color Differences* Fresh - Dry: Hue
Large	Parallel	2.7	28.2	15.2	40.8	2.52:1	1.4	8.3
	Counter	2.6	28.0	15.1	39.9	2.52:1	1.6	7.9
Medium	Parallel	1.9	28.4	20.4	53.4	2.43:1	1.6	7.3
	Counter	2.1	29.0	20.3	51.5	2.40:1	1.4	7.3
Small	Parallel	0.8	31.5	28.5	68.2	2.21:1	1.6	6.2
	Counter	0.6	32.1	28.7	67.8	2.10:1	1.7	6.1

*The color differences are based on the Munsell system of color showing hue and value (reflectance). The reflectance of dried prunes is less than fresh so that the value becomes less after dehydration. Hue moves toward the red as prunes dry and becomes a lower numerical figure.