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THE DEHYDRATION OF PRUNES

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INTRODUCTION

California is the leading state in the production of prunes, supplying the greater part of the domestic consumption in the United States as well as a considerable foreign exportation. Of the world commercial production(6) [3] in the years 1923–1927 California has produced an average of 66.2 per cent and the Pacific Northwest 11.3 per cent, the total United States production being 77.5 per cent. France, with 5.3 per cent, and Jugoslavia, exporting 17.2 per cent, have made up the remainder. The California prune acreage in 1928 was 193,000, of which 172,000 or 89.2 per cent was in bearing. The California production in 1928 was 220,300 tons. That of 1929, because of frost injury, is estimated at only 108,000 tons. Future production, owing to new acreage, is expected to reach even larger tonnage than that of 1928.

Unlike most fruits, prunes are rarely sold or canned fresh but are marketed almost entirely in the dried form. Therefore, drying is a most important operation and the profitable production of dried prunes is dependent on successful drying of the crop.

DEVELOPMENT OF DEHYDRATION

Sun-drying has been the standard and, until recent years, practically the only method of drying prunes in California. Artificial drying in evaporators was common during the early years of the prune industry, but was not so successful at that time as the sun-drying which displaced it. The few artificially heated dryers used were built by growers with little knowledge of the fundamental principles of dehydration. As a result, these older dryers were comparatively inefficient and expensive to operate and drying in them was slow and uneven. Consequently, they were only used to supplement sun-drying when weather conditions prevented natural drying. The popular

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[3] Superscript numbers in parentheses refer to "Selected References," page 32.

impression gained was that artificial drying could not compete with sun-drying, either in quality of product or economy of operation.

The interest in dehydration and its development during the world war contributed materially to an understanding of the economic application of the principles of heating and ventilating engineering to the evaporation of moisture from prunes. The work of state and federal investigators was instrumental in pointing out the proper construction and operation of dehydraters and in showing their advantages over the natural drying of prunes.

Since the year 1919 several commercial manufacturers have developed types of dehydraters which have proved successful both as to quality of product and economy of construction and operation. Many of the most experienced and successful prune growers, therefore, have installed and are continuing to use dehydraters to the exclusion of sun-drying. Their success with this modern method of drying is influencing other growers to make use of the advantages of dehydration.

The growth of the dehydration of prunes in the last few years has been steady and rapid. In 1921 49 dehydraters were operated on prunes and produced 2,946 dry tons, or 2.9 per cent of the crop. In 1928, according to figures from dehydrater manufacturers and prune packers, approximately 400 plants were operated and produced about 36,500 dry tons or 19.7 per cent of the crop. From 1925 to 1928, probably on account of the low prices brought by all prunes, the number of new plants built was sufficient only to keep pace with the large increases in production. The proportion of the crop dehydrated remained nearly constant during that period. The small size of the 1929 crop also discouraged the building of dehydraters.

RELATION OF DEHYDRATION TO SUN-DRYING

Success in drying prunes is measured by three main results:

1. Production of the finest quality of dried product permitted by the nature of the fruit harvested.
2. Production of the largest size and greatest weight of dried prunes through conservation of components of fresh prunes.
3. Lowest cost of drying consistent with fine quality and high yield.

Therefore, it becomes of interest to consider the relative merits of sun-drying and dehydration with respect to these three vital results.

COMPARATIVE QUALITY

The satisfactory drying of prunes requires not only the reduction of their moisture content to an amount which prevents spoiling by molding or fermentation but also certain modifications in color and flavor which have become trade standards. The skin should be black, the flesh a light amber color and have a sweet prune flavor free from sourness or caramelization.

If every prune season consisted throughout of hot dry weather conducive to rapid drying, there would not be necessarily any noticeable difference between naturally and artificially dried prunes. However, it is not uncommon for part of the drying season to consist of cold, damp weather accompanied by fog or showers. In some years, the duration of such unfavorable drying weather has been sufficient to cause the total loss of a considerable part of the crop through molding or fermentation. In other seasons of less unfavorable weather, actual spoilage losses have been slight, but a material proportion of the prunes have suffered injury to the color and flavor of the flesh because of a partial fermentation during the time drying was temporarily arrested. Such injury does not prevent the sale of the prunes, but definitely lowers their quality and consequently their market value. Many inferior prunes termed 'bloaters,' 'frogs,' 'chocolates,' 'slabs,' etc., must often be culled out to maintain the quality of the remainder of the crop. This not only causes a loss in yield but necessitates expensive hand sorting.

Proper dehydration not only gives rapid and continuous evaporation of the excess water but absolutely prevents deterioration in quality through mold or fermentation. Furthermore, since dehydration is conducted in a closed building by currents of warm air free from wind blown dust, it prevents the contamination of the fruit by dirt or insects that often occurs in sun-drying. Dehydration is in line with the modern demand for sanitary production of foods.

Not all dehydrated prunes have been of the best quality. In some cases inferiority has been due to the poor quality of the prunes before dehydration. Since dehydration is merely a dependable, controllable method for evaporating the excess water from fruits without injury to their quality, it cannot be expected to improve on the original qualities of the fruit. Rain-damaged prunes, salvaged by dehydration, should never be classed or judged as dehydrated prunes. In other cases, inefficient construction or operation of dehydraters has resulted in injury to the quality of the prunes during dehydration or in deterioration after dehydration because of improper or insufficient drying.

However, the great bulk of prunes dehydrated in recent years has been accepted and sold as being of the best market quality. The present consensus of opinion is that the quality of properly dehydrated prunes is at all times equal to and often superior to that of the sun-dried. Certain packers freely state their preference for the dehydrated product. It is quite possible that within the next few years dehydrated prunes will command a premium in price over the sun-dried. That they do not at present is probably due to the unstable condition of the prune market. For several years preceding 1929 the prune market was badly demoralized, making all prunes cheap, while in 1929 on account of the short crop all prunes are very high in price. Such conditions prevent the close discriminations in price that may be made under more normal circumstances.

COMPARATIVE YIELD

It has long been known that if, as a result of unfavorable weather conditions, prunes undergo a partial fermentation during sun-drying, the yield of dried product is materially reduced. This is explained by the fact that when the sugar in the prunes is fermented by ever-present yeasts, it changes into alcohol and carbon dioxide gas. Since both these compounds are volatile, they evaporate into the surrounding air and thereby cause a loss in weight of solid matter proportional to the extent of the fermentation. When the prunes become sufficiently dried, the action of microorganisms is arrested and further loss in weight on this account is prevented. The temperatures normally used in dehydraters are above the temperatures at which fermentation organisms act and consequently such losses are prevented by dehydration.

The living tissues of prunes constantly undergo the process of respiration, during which certain enzymes normally present change some of the sugar to carbon dioxide gas and water, compounds that evaporate from the fruit. When the fruit is removed from the tree it no longer receives from the tree sugar to compensate for this loss, but the enzymes remain active and the respiration process continues for some time. While the brief heating incident to lye-dipping tends to reduce subsequent respiration losses, in sun-drying a small but definite loss of sugar occurs and does not entirely cease until the prunes are dry. The high temperatures, and probably more important, the short drying time required in dehydrating promptly stop respiration and minimize losses therefrom.

These statements are borne out by the detailed investigation reported in the original edition of Bulletin 404 which showed, when proper adjustment for moisture content is made, that:

1. Dehydration results in a greater weight of dried prunes than does sun-drying.
2. Dehydration results in a greater size or lower count per pound.
3. Dehydration results in the retention of a greater amount of sugar. Records of relative yields kept by a number of growers support this observation and in many cases the increased return has been sufficient to pay the cost of operating the dehydrater.

TABLE 1

COMPARITIVE COSTS OF SUN-DRYING AND DEHYDRATING PRUNES
(Per Fresh Ton)

	Requirement for dehydrating	Cost	
		Dehydrating*	Sun-drying†
Labor:			
Average	6.08 man hours	$2.60	$3.89
Maximum	10.4 man hours	4.23	
Minimum	3.46 man hours	1.38	
Fuel:			
Average	20.2 gallons oil	1.06	0.16
Maximum	40.7 gallons oil	2.05	
Minimum	10.4 gallons oil	0.48	
Power:			
Average	32.0 kw-hr.	0.70	0.05
Maximum	68.0 kw-hr.	1.70	
Minimum	13.0 kw-hr.	0.33	
Lye:			
Average	1.8 pounds	0.13	0.11
Maximum	10.0 pounds	0.55	
Minimum	1.3 pounds	0.04	
Total operating cost:			
Average		$4.47	$4.21
Maximum		7.41	
Minimum		2.84	

* Observations on 25 air-blast dehydraters 1920–28.

† Average of 11 dry-yards (See: Christie, A. W., and L. C. Barnard. The principles and practice of sun-drying fruit. California Agr. Exp. Sta. Bul. 388: 1–60. 1925.)

COMPARATIVE COSTS

The fine quality and greater yield and size of dehydrated prunes would probably be of little interest to growers if such gains were counterbalanced by a greater cost for dehydration. Fortunately, however, the construction and operation of dehydraters have attained such efficiency that the advantages of dehydration are obtainable at little or no greater total cost than that of sun-drying in favorable weather, while in unfavorable weather dehydration is often less expensive. Table 1 shows the range and average of costs observed.

Fixed Charges.—A consideration of relative costs would be incomplete without including comparative fixed charges on the equipment required in the two methods of drying. In calculating fixed charges, it is necessary to include interest on the investment, depreciation and upkeep, taxes and insurance on all land, buildings, and equipment used for drying or handling the prunes after harvesting. The fixed charge per ton of prunes dried naturally varies with initial investment in equipment and with the annual tonnage of fruit dried. It is often sound economy to sacrifice a little operating efficiency in order to obtain a greater saving on investment and fixed charges. Fixed charges may also be reduced by increasing the tonnage dried. Custom dehydration is one way of accomplishing this, and the usual charge of $10 to $15 a fresh ton compared with an average total cost of $8 indicates that it may readily be profitable. Community dehydration is another means of increasing tonnage and reducing fixed charges, but requires true cooperative spirit and efficient, impartial management.

In sun-drying, the much greater investment in land and trays often balances the cost of a dehydrater. The area of dry yard is normally estimated at one acre for each 20 acres of orchard, while a dehydrater of equal capacity occupies only about 5 per cent of this area, including the space required for dipping and storing the fruit. Most dry-yard land has a potential value equal to that of the surrounding orchards.

Since sun-drying trays are rarely used more than twice a season, while dehydrater trays are usually used at least once every two days, the tray surface required for dehydration is only 10 to 15 per cent of that required for sun-drying.

It is customary to figure the annual fixed charges on sun-drying equipment at from 15 to 20 per cent on the total investment, which investment averages $20 per fresh ton of prunes dried per annum. According to figures previously presented,(1) the average fixed charge for sun-drying prunes is $3.43 per fresh ton.

In dehydration, interest on the entire investment is usually placed at 6 or 7 per cent. On modern types of fireproof dehydraters a charge of 7½ per cent on the entire investment will normally be adequate to cover all depreciation and upkeep. Taxes are variable but rarely exceed 3 per cent on an assessed valuation equal to 50 per cent of the actual value. Many owners of fireproof dehydraters carry no insurance, while some carry insurance only on the wooden buildings, trays, etc., used in connection with the dehydrater.

Adding these charges it is found that the total fixed charge on a substantially built fireproof dehydrater, together with accessory buildings and equipment, will average 16 to 17 per cent per annum on the investment, which investment averages $22 per fresh ton of prunes dried per annum.

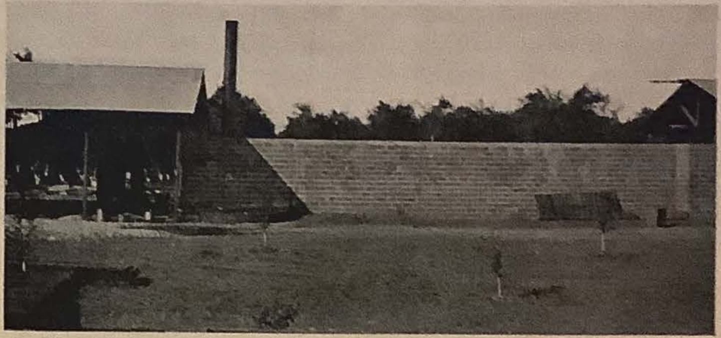

Fig. 1.—One of the first modern air-blast tunnel dehydraters (built in 1921). Note young prune trees in former dry yard.

TABLE 2

Fixed Charges on Prune Dehydraters

	Total investment	Seasonal tonnage	Fixed charges, per fresh ton				
			Interest at 7 per cent	Depreciation at 7½ per cent	Taxes	Insurance	Total
Average	$10,820	492	$1.60	$1.71	$0.30	$0.04	$3.65
Maximum	19,300	733	2.46	2.64	.40	.18	5.37
Minimum	6,000	201	0.94	1.01	0.16	0.04	2.15

The figures on fixed charges in 6 modern air-blast dehydraters given in table 2 show an average fixed charge of $3.65 per ton for dehydrating. Comparing this with the corresponding average of $3.43 for sun-drying, it is seen that fixed charges for dehydration are only slightly greater than for sun-drying. Adding the comparative operating costs given in table 1 to the corresponding fixed charges it is found that the average total cost of dehydrating is $8.12 per fresh ton as compared with $7.64[8] for sun-drying, a difference which is probably not significant. Using the even amount of $8 a fresh ton and an average drying ratio of 2.5 to 1, it is evident that the cost of drying prunes is approximately one cent a dry pound. It may be concluded that the average total cost of dehydration is no greater than for sun-drying if based on present prices for complete new equipment in each case.

Growers who already have adequate sun-drying equipment, in most cases purchased at considerably less than present prices, may find the investment and therefore the fixed charges on a new dehydrater to be temporarily somewhat greater than on their dry-yard. However, many such growers have installed dehydraters, sold most of their trays and made their dry-yard land more profitable by planting it to trees (see fig. 1), feeling that the economic advantages of dehydration are more than sufficient to balance a slightly greater fixed charge.

Growers who must provide new or additional drying equipment for young orchards coming into bearing will, with few exceptions, find it advantageous to employ dehydration rather than sun-drying.

SUMMARY OF COMPARISONS

Summarizing the foregoing comparisons, it can be fairly said that dehydration produces prunes of equal or better quality than the sun-dried, generally results in a greater yield and size of prunes, and provides insurance against rain-damage losses, and that the total cost of operating an efficient dehydrater, including fixed charges, need be no greater than for a dry-yard of equal capacity. Consequently, growers who can finance the installation of a dehydrater or who can have their prunes dehydrated at a reasonable custom charge will find it to their financial advantage to adopt this modern method of drying.

PRINCIPLES OF DEHYDRATION

Dehydration may be defined as the evaporation of water from substances in a current of air, the temperature, humidity and flow of which are subject to control. The fundamental laws of physical science on which dehydration is based have long been known and used in heating and ventilating engineering. The practical application of these principles to the dehydration of fruits has already been presented in detail in several technical publications (see list of references, page 32). Since very few growers build their own dehydraters, it is not necessary in this bulletin to give all details governing design and construction. However, in order that growers may have the necessary information to select and operate a dehydrater intelligently, the following brief elementary presentation of the principles of dehydration is given:

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[8] One of the oldest and largest non-profit cooperative dry yards in Santa Clara County makes a charge of $8 a ton for drying and storing prunes.

HEAT REQUIREMENTS

By evaporation of water is meant the change of water from the liquid to the vapor state. To accomplish this change requires the expenditure of a definite amount of heat. In sun-drying, this heat is derived from the sun, while in dehydration it is produced by the combustion of fuel. The unit used to measure heat in dehydration is the British thermal unit (hereafter referred to as B.t.u.) which represents the amount of heat absorbed in raising the temperature of one pound of water one degree Fahrenheit.

If prunes at a temperature of 60° F are placed in a dehydrater and dried at an average temperature of 150° F, 90 B.t.u. will be required to raise the temperature of each pound of water in the prunes from 60° to 150° F. The heat required to transform one pound of water from the liquid to the vapor state at 150° F is 1,010 B.t.u. Consequently, the total amount of heat theoretically required to heat the water in the prunes to the average temperature of the dehydrater and then evaporate that water is 90 plus 1,010 or 1,100 B.t.u. per pound of water evaporated. The actual amount of heat theoretically required will vary somewhat with the original temperature of the prunes and the average temperature at which the dehydrater is maintained. However, for practical purposes, 1,100 B.t.u. per pound of water evaporated may be taken as the basic requirement.

Heat must also be provided for other purposes. The walls and roof of the dehydrater are constantly radiating heat which must be replaced in order to maintain the dehydrater at the desired temperature. The solid matter of the fruit and the trays and cars which carry the fruit enter the dehydrater cold and emerge at an elevated temperature and consequently carry away the heat which they have absorbed. Heat is lost from the smoke stack in order to provide draft. Heat is also lost with the warm exhaust air which removes the water vapor and through leaks. None of these losses can be entirely eliminated but all can be minimized by proper construction and operation. The over-all fuel efficiency of prune dehydraters has been found to vary considerably with the type of construction and with the relative temperatures of the inside and outside air. Numerous tests show that efficiently constructed and operated dehydraters generally give an over-all fuel efficiency of 40 per cent or higher. Taking 45 per cent efficiency as an average figure, the total heat requirement is 1,100 ÷ 0.45, or 2,444 B.t.u. per pound of water evaporated.

FUELS

Of the common sources of heat, oil is the most convenient and economical in California for dehydrating prunes and is therefore almost universally used. Wood and coal necessitate additional expense for handling and unless used as a source of steam heat cannot be easily controlled. Cheap natural gas, while an excellent fuel, is not available in most prune districts. Electricity is a convenient and efficient source of heat but even at a rate as low as 1 cent per kilowatt hour, the cost of electrical heat for dehydration is prohibitive.

HEATING SYSTEMS

There are three types of heating systems: direct heat, direct radiation, and indirect radiation.

Direct heat means the absorption of the heat from the burning fuel by the air used to dry the prunes, without the intervention of furnace walls or flues. The hot gases from the combustion of oil or gas are drawn into and mixed with the main air stream in such proportion as to give the resultant mixture the desired temperature. The advantages of this system are:

1. Reduction in fuel consumption through elimination of stack losses.
2. Lower cost of installation.
3. Reduced depreciation and upkeep charges as compared with radiation systems.

Common disadvantages of this system have been:

1. The use of higher priced partially refined oils to insure complete combustion.
2. The potential danger of contaminating the fruit with unburned fuel or soot.

While there have been few cases of fruit being injured by this method, many thousands of tons of prunes have been successfully dehydrated by direct heat. Observations show no consistent difference in quality of fruit and fuel charges between the direct heat and direct radiation systems at present in use, but indications point to lower upkeep costs for the direct-heat system.

Direct radiation means the radiation of heat through the metal walls of furnaces and flues directly into the air used in drying. This is the system in most common use for fruit dehydraters. If properly constructed, this system prevents possible contamination of fruit by unburned fuel and gives relatively high fuel efficiency. Its sole disadvantage has been the occasional replacement of burnt-out flues, especially those nearest the high temperature of the furnace. By using flues of such length and radiating surface that the stack temperature is as low as is consistent with adequate draft, or by using forced draft, furnace efficiencies of 70 to 80 per cent are possible with this system.

Indirect radiation means that the heat from the fuel is transferred to the drying air through the intermediate agency of a steam boiler and steam heating coils. Possible advantages of this system are that any kind of fuel can be used and the temperature of the drying air can be automatically controlled by a thermostatic steam valve. The disadvantages of the steam heating system are its relatively greater first cost and the fact that it cannot at best give an air-heating efficiency of over 50 to 60 per cent.

Thermal Efficiency.—The over-all thermal efficiency can be easily calculated by use of the following formula:

$$\frac{\text{Pounds water evaporated} \times 1{,}100\ \text{B.t.u.}}{\text{Gallons oil consumed} \times 142{,}000\ \text{B.t.u.}} \times 100 = \text{over-all efficiency, per cent}$$

The pounds of water evaporated during a given time, usually 24 hours, is determined from the difference in weight between the fresh fruit entering and the dried fruit leaving the dehydrater.

AIR FLOW REQUIREMENTS

Air performs two essential functions in a dehydrater. First, it conducts the heat from the air-heating system to the fruit which is to be dried and, second, it absorbs and removes the water vapor which that heat has evaporated from the fruit. It is obvious, therefore, that the capacity of any dehydrater to dry prunes depends not alone on the temperature of the air but more particularly on the volume of heated air which is brought into contact with the prunes. More dehydraters have failed to give the expected capacity or efficiency because of inadequate air flow than from all other causes combined. For accuracy in dehydrater calculations air must be considered as a mixture of dry air and water vapor, both of which contain heat. When this air mixture comes in contact with moist prunes, a drop in the temperature of the air takes place, indicating that part of the heat in the air mixture has been used in changing water in the prunes from the liquid to the vapor state. Consequently, the amount of evaporation which takes place depends, first, on the drop in temperature of the air, and, second, on the volume of that air passing over the prunes in a given time.

For example, let it be assumed that air enters the drying chamber at a temperature of 165° F, and a relative humidity of 25 per cent. By reference to tables of composition, one cubic foot of this air is found to contain 0.0578 pounds of dry air and 0.0036 pounds of water vapor or a total of 0.0614 pounds of air mixture per cubic foot. The amount of heat which this air can give up in dropping one degree is determined by multiplying the pounds of dry air and of water vapor by their respective specific heats[6] and adding these two results together. This gives 0.0155 B.t.u. as the amount of heat given up by one cubic foot of this air mixture in dropping 1° F. If the above air mixture in passing through the drying chamber has a temperature drop of 35° F, each cubic foot of air will give up 35 times 0.0155 or 0.5425 B.t.u. of heat. Since each pound of water evaporated theoretically requires 1,100 B.t.u. the volume of air which must pass through the drying chamber to evaporate one pound of water per minute would be 1,100 divided by 0.5425 or 2,028 cubic feet per minute. However, a part of the heat given up by this air will not be available for evaporation because it will be lost by radiation or leaks or in heating trays, cars, etc. Consequently, an additional amount of air must be provided to compensate for these heat losses. Assuming the air to have an actual evaporating efficiency of 75 per cent, 2,704 cubic feet of air per minute will be required for each pound of water to be evaporated per minute.

METHODS OF SECURING AIR FLOW

Natural draft is the oldest and simplest method of inducing air flow. The advantage of this system is that it does not require the use of power-driven fans. The disadvantages are:

1. Inadequate volume and velocity of air for all but small units.
2. Lack of control of air distribution, causing uneven drying.

3. Difficulty of securing quick and exact control of temperature and humidity.

Natural-draft dryers are now used only by growers with small tonnages. Their total cost per ton of operation, including fixed charges, is usually much greater than that of fan-equipped dehydraters.

Air-blast dehydraters are those in which the air flow is produced by power-driven fans. The advantages of this system are that it permits exact control of the temperature, humidity, volume, and distribution of the air. Although requiring a considerable investment in one or more fans and motors, this extra cost is well repaid by more rapid and uniform drying and greater economy.

The fans used in dehydraters are of two main types: disk or propeller fans and centrifugal fans which include multivane and steel-plate types. Dehydraters of small capacity or those with a series of fans for supplying air to several sections have used disk or propeller fans satisfactorily. In large dehydraters where a large volume of air must be circulated through a long drying chamber, the centrifugal fan is the most efficient because of its ability to produce an adequate flow of air against relatively high frictional resistance.

Position of Fans.—This is determined by the preference of the designer. There are two usual positions in which the fan is placed:

1. Blowing directly through the drying chamber and returning the recirculated air by drawing it through the heating chamber. This keeps the drying chamber under slight pressure so that air leakage will be outward, but it may draw flue gases from leaks in the heating system. This system insures uniform air temperature because of the mixing action of the fan after the air is heated, and permits uniform distribution of the air by proper placing of the fan discharge and, if necessary, the judicious use of baffles.

2. Drawing directly from the drying chamber and returning the recirculated air by blowing it through the heating chamber. This tends to draw cold outside air into the drying chamber through leaks and has generally resulted in less even distribution of air. Placing the fan in the heating chamber and separating the fan intake from the drying chamber by dampers prevents in leakage of flue gases, and eliminates the other objections listed above by keeping both heating and drying chambers under slight pressure.

The air pressure produced by a fan is divided into velocity pressure and static pressure, the sum of which equals the total pressure. Static pressure may be defined as the pressure required to overcome

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[6] *Specific heat* is the ratio between the heat required to raise (or, conversely, given off by cooling) one pound of any substance 1° F, and that required to raise one pound of water 1° F, the specific heat of water being considered as 1. The specific heat of dry air and of water vapor are taken as 0.24 and 0.45 respectively.

the frictional resistance to the passage of air. The static pressure in dehydraters is usually found to be between 1 and 2 inches of water column. In good average practice the static pressure is about 1.5 inches. Long, narrow, and crooked passages or obstructions increase static pressure and consequently decrease the volume of air passing. Therefore, it is essential that all air passages used for heating, drying, and recirculating be as short and straight as possible. At no point in the entire system should the free cross-sectional area be less than that between the trays, and it should be large enough to avoid an air velocity greater than 1,000 lineal feet per minute. The aggregate area of the air passage between the ends of the trays should be about 60 per cent of the total cross-sectional area of the drying chamber.

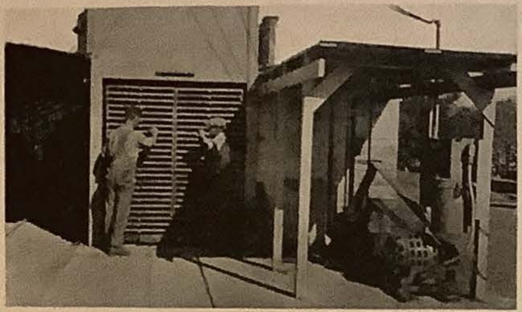

Fig. 2.—Placing a car of prunes in a tunnel dehydrater. Note how closely the stacks of trays fit the tunnel.

Air Distribution.—In order to secure the maximum drying efficiency of the air, the stacks of trays should as nearly as possible fill the entire cross-sectional area of the drying chamber, leaving barely sufficient clearance for movement of cars as illustrated in figure 2. Flexible baffles, commonly made of discarded canvas belting or hose, are advantageously used to prevent excessive flow of air over the top trays, along the walls, and under the cars. In short, every effort should be made to cause all the air to flow between the trays.

The free air space between the ends of the trays usually varies from one to two inches in height, preferably nearly two inches. If these air spaces are so narrow as to materially restrict the air flow, drying will be slow and uneven. On the other hand, if unnecessarily wide, more rapid drying will not compensate for the decreased holding capacity of the dehydrater.

Air Measurement.—A simple method of measuring the air flow in dehydraters is by the use of an anemometer which shows the distance in feet which air moves. By noting the distance air moves in one minute, the velocity is obtained, and by multiplying this by the area of the opening measured, the volume of air in cubic feet per minute is obtained. All modern air-blast dehydraters show an average air velocity between trays of 500 lineal feet per minute or over, generally 600 to 700. Velocities below 500 feet are generally associated with slow and uneven drying while velocities in excess of 1,000 feet are not enonomically practicable.

Power for Fans.—Fans, and burners, require about 1½ horsepower for each fresh ton of prunes dried per 24 hours. Electricity is the most convenient and economical source of power. A metal link chain is an efficient fan drive although more expensive than endless water-proof leather belts which have also given excellent results in dehydraters. Rubber fabric belts have been found less efficient and shorter-lived in dehydrater work.

HUMIDITY CONSIDERATIONS

Definition of Humidity.—The water vapor present in air is commonly expressed as relative humidity, or the percentage of the weight of water vapor in a given space to the weight of water vapor which the same space at the same temperature could hold if it were saturated with moisture. Saturated air has a relative humidity of 100 per cent and absolutely dry air of 0 per cent.

Measurement of Humidity.—Relative humidity is determined by the comparative readings of two thermometers, one having a dry bulb and the other having its bulb closely covered by a *clean* wick kept moist by distilled water. These thermometers are placed near together but not touching in the direct air flow of the drying chamber. For correct readings the air velocity should be at least 500 lineal feet per minute. The lower the moisture content of the air, the lower will be the reading of the wet bulb thermometer. Use has been made of this simple principle in preparing such charts as that in figure 3, giving the relative humidity of the air for any combination of wet and dry bulb temperatures. Such a chart on a card will be furnished to anyone making request to the Fruit Products Laboratory at this Station.

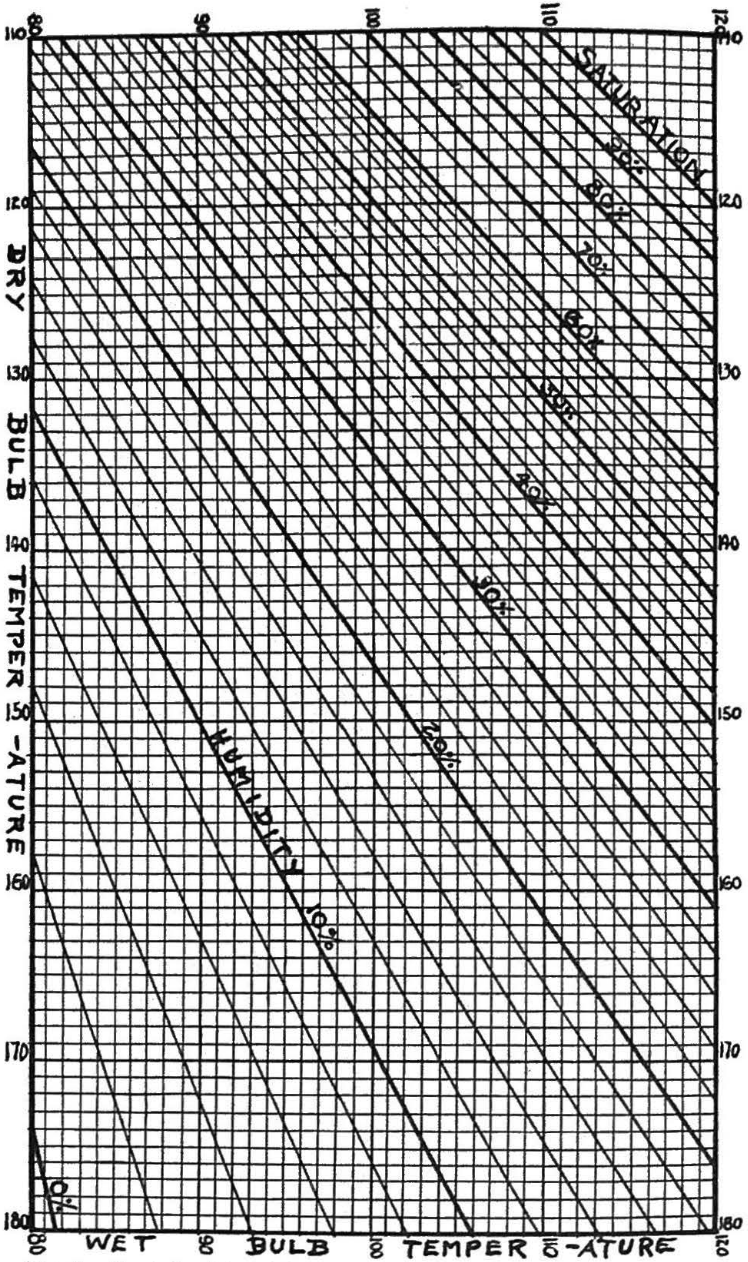

Fig. 3.—Chart for determining relative humidity from wet and dry-bulb temperatures. (Drawn by G. B. Ridley.)

In this chart, to find the relative humidity, follow the cross-section line corresponding to the dry-bulb temperature until it intersects the cross-section line corresponding to the wet-bulb temperature observed. From the relation of this point to the diagonal lines the relative humidity may be read. For example, at a dry-bulb temperature of 150° F and a wet-bulb temperature of 110° F the relative humidity is 28 per cent.

Effect of Temperature on Humidity.—The moisture-holding capacity of air approximately doubles for every 27° F rise in temperature. For example, if a given weight of air outside a dehydrater had a temperature of 57° and a relative humidity of 100 per cent, as might be the case on a rainy or foggy day, and if this air were drawn into the dehydrater and heated to 165° F, it would have a relative humidity of only about 6 per cent, or in other words, the same weight of air could hold 16 times as much water as it originally held. These figures explain why dehydraters continue drying independently of the humidity of the external air.

Recirculation.—If a dehydrater were hermetically sealed to prevent interchange of air with the outside and the air within continuously recirculated and reheated it would soon reach saturation and drying would cease. If, on the other hand, air were drawn into a dehydrater, heated and then discharged after passing over the fruit only once, an excessive amount of heat would be wasted with the exhaust air. The volume of air required for absorption of the moisture evaporated from the fruit is on the average only 1/7 to 1/8 as much as the volume of air necessary to convey the heat required for evaporation. By recirculating the proper proportion of warm exhaust air the humidity of the air entering the drying chamber can be maintained at any desired percentage and drying will progress steadily with the minimum loss of heat in the exhaust air. Practical experience has shown that partial recirculation decreases fuel consumption at least 50 per cent without decrease in the rate of drying, and all commercially built dehydraters now use this system. Because of their length and complexity, calculations on control of recirculation are omitted from this bulletin but are available elsewhere.(2)

CONSTRUCTION AND EQUIPMENT

Fire-proof construction is preferred for dehydraters, hollow tile or concrete blocks being the materials most commonly used. Double walls of sheet metal, asbestos, or various building boards have been successfully used and are less expensive. Solid concrete is no longer much used. Plants built of wood are very susceptible to fire when in operation and hence most needed. In any case the construction should be tight to prevent air leakage, and the doors should be substantial and well fitted.

The oil burner, furnace, flues, fan, motor, and other vital parts of the dehydrater should be of adequate size, strongly constructed, and firmly mounted.

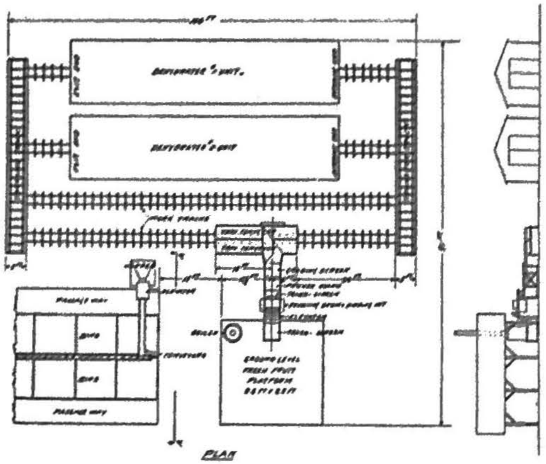

Fig. 4.—Suggested arrangement for a prune dehydrater.

Accurate wet and dry bulb thermometers should be provided. Recording thermometers, while comparatively expensive and not strictly necessary, furnish a permanent and valuable check on the operation of the plant.

The minimum number of cars and trays required for dipping and drying is 50 per cent in excess of the holding capacity of the dehydrater. Experienced operators state that 100 per cent excess is required to obtain maximum flexibility and efficiency. Solid-bottom field trays, with sides or ends reconstructed so as to permit adequate air flow between the trays when stacked, are commonly used. However, if new trays are to be provided special dehydrater trays with slat bottoms will generally give slightly more rapid and more even drying than solid-bottom trays. Screen trays are more expensive and after being used for some time, the sagging of the screen causes uneven drying.

For ease in handling the heavy loads of trays, the cars should be equipped with roller bearings and in large dehydraters a winch and cable is necessary for moving the cars through the dehydrater.

The ideal arrangement of the plant for economy of labor is that in which the prunes move from the receiving platform to the storage bins in a continuous, unimpeded circuit by the shortest practical route, the trucks of emptied trays being conveniently returned to the loading point. Most of the labor in dehydration is required before and after drying rather than during drying. The compactness of the plant is also of importance in securing a neat appearance and economy of ground space as well as a saving in the construction of roof area, tracks, etc. It is impossible to present a plan which will exactly fit all cases, but the plan presented in figure 4 will fit most installations and is susceptible of adaption to any dehydrater now in use. The main features of this plan are:

1. All the operations of receiving, dipping, grading, loading and unloading trays are concentrated in one location so as to be always under the direct observation of the person in charge.

2. The path of the prunes is such that they constantly move forward without retracing of routes, thereby preventing interference of the cars of fresh fruit with those holding dried fruit.

3. The emptied trays are available for reloading at a point close to the dipper discharge, thereby avoiding extra handling of empty cars and trays.

CALCULATION OF DEHYDRATER REQUIREMENTS

The following typical example of dehydrater requirements is presented as a guide in determining the adequacy of a dehydrater and its essential parts. Let it be assumed that a certain prune grower must have a dehydrater capable of dehydrating 10 fresh tons in a day of 24 hours in order to accommodate the peak load of a normal harvest and that these prunes will have an average drying ratio of 2.5 to 1.

Assuming an average drying time of 24 hours, the dehydrater must have a holding capacity of 20,000 pounds of fresh prunes. If the trays have an average load of 3.5 pounds per square foot, 5,714 square feet of tray area must be provided for in the dehydrater. If two stacks of 3 × 8 foot trays, 25 high, are used to the truck, the capacity should be 5 such trucks; if 3 × 3 foot trays, 13 trucks.

To dehydrate 20,000 pounds of prunes with a drying ratio of 2.5 to 1 in 24 hours, necessitates the evaporation of 12,000 pounds of water or 500 pounds an hour. Assuming an over-all fuel efficiency of 45 per cent, 2,444 B.t.u. per lb. of water evaporated will be required (see page 12) or 1,222,000 B.t.u. per hour. Assuming a heat value of 142,000 B.t.u. for a gallon of oil, 8.6 gallons of oil must be burned. Consequently a burner of not less than 9 gallons capacity an hour should be provided. For capacity of oil burners reference should be had to the catalogs of firms manufacturing oil burners for dehydraters.

If the direct-radiation system be used, it is essential that the total surface area of furnace and flues be adequate to radiate the required heat. The surface required varies greatly with the nature of the furnace and flues and no exact figure can be given. With the common steel radiating furnace and flues, from 400 to 500 square feet is usual for a plant of this size.

An evaporation of 500 pounds of water an hour is equal to 8.33 pounds a minute. By reference to the figures on page 14 it can be seen that if the air has a temperature drop of 35° F and an evaporating efficiency of 75 per cent in passing through the drying chamber, each pound of water to be evaporated each minute requires the passage of 2,704 cubic feet of air. Consequently, an evaporation of 8.33 pounds of water (one gallon) a minute will require 22,532 cubic feet of air a minute.

If this entire volume of air is to be delivered by a single fan, a multivane fan will be best. In some types of dehydraters, a number of smaller fans, usually of the disk type, are used to give the total air flow required. No portion of any air passage should have a cross section area less than that of the fan discharge connected to it. If the total air flow is delivered by a single fan, no part of the entire air system should have an area of less than 22.5 square feet, except at the fan. The total free area between the ends of the trays (see page 17) should be about 30 square feet, which will give an air velocity of 750 lineal feet a minute between trays.

Most fan manufacturers furnish tables of performance which show for each size of fan the volume of air delivered at a given speed and a given static pressure and the horsepower required. By reference to such tables and to price lists, selection can be made of the fan which will most economically deliver the volume of air required. The static pressure in dehydraters usually varies from 1 to 2 inches. If the dehydrater is constructed with attention to the principles regarding the free area and construction of air passages, an average static pressure of 1.5 inches is ordinarily used in determining fan capacities.

The foregoing paragraphs have given briefly the most important factors concerned in the construction of any dehydrater, namely, its holding capacity for prunes and the amount of heat and air required to dry the prunes in a given time. The figures used in the example are purposely conservative and many dehydraters show greater efficiency. For instance, if the drying ratio is less than 2.5:1 or the fuel efficiency more than 45 per cent, correspondingly less heat and air will be required to dry the same weight of prunes in the same time.

SELECTION OF A DEHYDRATER

The following three courses are open to growers who wish to install a dehydrater:

1. Purchase of a standard commercially built dehydrater.
2. Construction of a dehydrater from plans furnished by a dehydrater manufacturer or engineer.
3. Construction of a dehydrater from an original design.

Most growers find it simpler, safer, and just as inexpensive to buy a standard commercial dehydrater as to design or build their own plant. The few growers who have been successful in building their own dehydraters are usually men with previous experience in construction or engineering work. Without some technical training or experience in such matters, it is inadvisable for a grower to attempt the construction of a dehydrater. Some growers have the impression that dehydrater manufacturers charge excessive profits, but such is not generally the case. The quantity purchase of materials and equipment at low prices and the employment of experienced mechanics enables large dehydrater manufacturers to sell plants at a profit for a price little, if at all, greater than that for which a grower could build a single plant.

There have been several instances of successful dehydraters built by growers from plans obtained from dehydration engineers. If such plans have been demonstrated to give an efficient dehydrater, some saving can often be effected by this scheme.

The University of California does not furnish plans for dehydraters. No service of this sort is contemplated beyond reprinting in this publication a drawing (fig. 5) illustrating a dehydrater designed by Christie and Ridley and published by them in 1923.(2) From this drawing several growers with construction experience have copied the dehydrater, which has given as rapid, uniform, and economical drying as any other type. While this design utilizes the best principles of the straight air-blast tunnel dehydrater it is not identical in design with that of any patented or commercially built dehydrater.

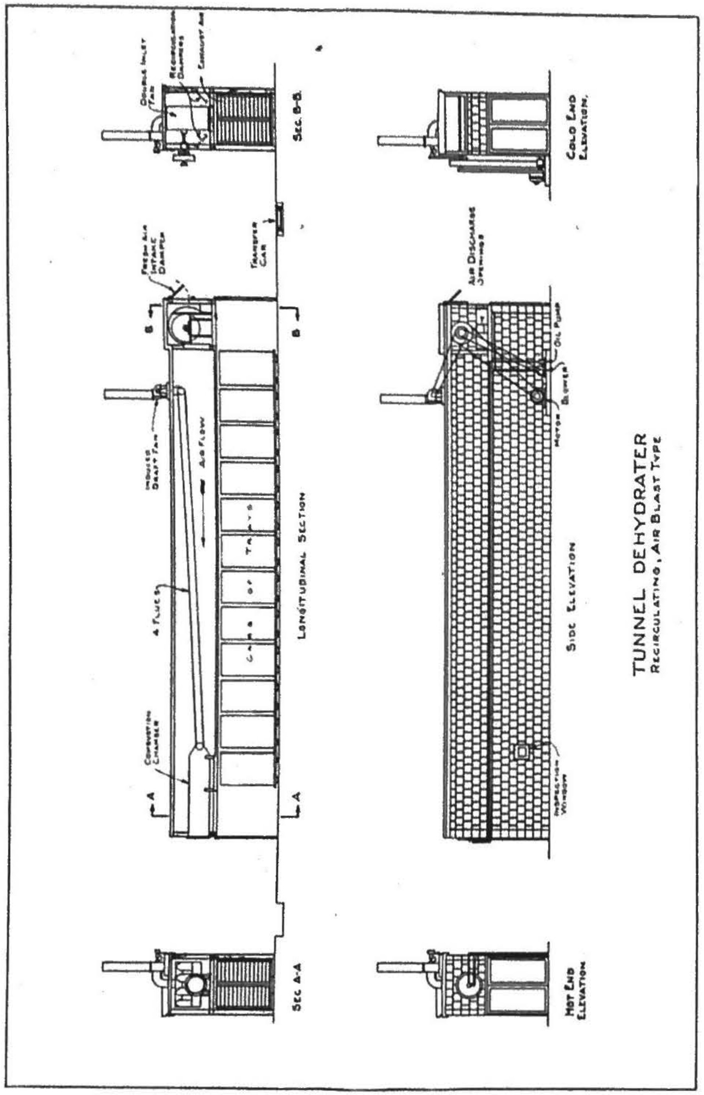

Fig. 5.—Recirculation air-blast tunnel dehydrater (after Christie and Ridley).

Descriptions of the leading types of commercial dehydraters are not included because they are preferably obtained from pamphlets issued by the manufacturers or better by inspecting the dehydraters. Growers are strongly urged to confine their selection of a dehydrater to types which have already been built and operated so as to demonstrate their capacity and efficiency. Persons wishing to manufacture and sell dehydraters should not expect growers to invest in a machine until the prospective manufacturer has demonstrated his claims by operating such a dehydrater through a prune season.

DEHYDRATER MANUFACTURERS

The following list includes the names of all persons or firms that are known to have sold dehydraters since 1925. Persons formerly in this business but not active therein at present or persons seeking to sell dehydraters but who have not yet succeeded are not included:

Chapman Dehydrater Co., Inc., 12th and D Streets, Modesto.
W. W. Cozzens, 10 Broadway, San Jose.
O. S. Crenshaw, Coyote.
Knipschild Dehydrater Co., St. Helena.
L. N. Miller, Eugene, Oregon.
The Oliver Co., 670 Lincoln Ave., San Jose.
Rees Blowpipe Manufacturing Co., 340 Seventh St., San Francisco.
G. B. Ridley, Dehydration Engineer, 255 California St., San Francisco.
R. L. Puccinelli, Los Gatos.
E. L. Younger, Woodland.

PATENT SITUATION

Any grower designing his own dehydrater should do two things before beginning construction, first, have the plans and specifications checked by a compentent authority to ascertain if they will accomplish the desired result and, second, ascertain if the design infringes any dehydrater patent. While there is no basic patent covering the dehydration of prunes, most types of dehydraters in use are protected in whole, or in part, by patents. These patents are of the type commonly referred to as 'construction patents' and care should be taken to avoid legal entanglements occasioned by unauthorized duplication of patented features. One should not be misled by the common misconception that a grower building a dehydrater exclusively for his own use is exempt from patent infringement claims. Several damage suits have been brought for infringement of dehydrater patents but the situation remains uncertain pending clarification through judicial decision.

Of the many hundreds of patents granted on dehydrating equipment, those given in table 3 have been selected as of the greatest present importance in avoiding possible infringements when new types of dehydraters are built and used.

TABLE 3

PATENTS ISSUED TO CALIFORNIA MANUFACTURERS OF DEHYDRATERS

Number	Filed	Granted	Issued to
1,461,224	Dec. 13, 1919	July 10, 1923	J. W. Pearson (Associate of G. B. Ridley)
1,413,135	Jan. 15, 1920	Apr. 18, 1922	Claude Rees (Progressive Dehydrater Co.)
1,404,369	May 1, 1920	Jan. 24, 1922	F. C. Chapman
1,422,416	Sept. 28, 1920	July 11, 1922	F. C. Chapman
1,464,338	June 29, 1921	Aug. 7, 1923	R. L. Puccinelli
1,528,223	Feb. 21, 1922	Mar. 3, 1925	C. C. Moore
1,532,303	Dec. 4, 1922	Apr. 7, 1925	W. W. Cozzens
1,543,947	Aug. 13, 1923	June 30, 1925	C C. Moore
1,593,378	Nov. 5, 1925	July 20, 1926	J. M. Younger
1,602,988	Nov. 18, 1925	Oct. 12, 1926	L. N. Miller
1,645,738	Apr. 7, 1926	Oct. 18, 1927	F. C. Chapman
1,645,760	May 10, 1926	Oct. 18, 1927	F. F. Knipschild
1,648,468	Mar. 5, 1927	Nov. 8, 1927	E. L. Younger
1,718,845	Mar. 10, 1928	June 25, 1929	E. L. Younger

A copy of any patent can be obtained by sending ten cents in coin to the U. S. Commissioner of Patents, Washington, D. C. A patent attorney should be consulted on questions concerning infringement.

OPERATION OF DEHYDRATERS

The methods of harvesting, dipping and traying prunes are primarily the same whether the prunes are to be sun-dried or dehydrated. These have already been described in Bulletin 388,(1) and need not be repeated here. The operation of dehydraters is best learned by experience, supplemented by visits to efficiently operated plants. No one system will fit all types of dehydraters or all varieties of prunes. However, in order that operators may be guided in the right direction, the following principles of operating prune dehydraters are presented:

DIPPING

Lye dipping of prunes is not as essential in dehydration as in sun drying, though it is customary and desirable. It should be followed by rinsing in clear water, preferably with sprays. Over-dipping should be avoided, for it causes prunes to bleed or drip and stick to the trays. On this account tender-skinned varieties such as the Imperial may better be dipped in plain hot water.

GREEN GRADING

If the fresh fruit varies much in size or moisture content and if the plant is large enough to permit drying the different sizes on separate trucks, green grading is usually to be recommended. Under these conditions it promotes even drying and increases the capacity of the plant by taking advantage of the shorter drying time of small fruit. Unless these conditions do prevail, however, it may be better economy to dispense with green grading for the sake of the greater simplicity of handling and efficiency of labor without it.

TRAYING

For continuous spreading of dipped and graded prunes and minimum handling of trays, the diagonal discharge illustrated in figure 4 has given satisfaction. A continuous stream of empty trays on a roller conveyor is passed under the ends of the grader, the diagonal discharge being so regulated that the prunes are evenly distributed over the entire tray with little hand spreading. To facilitate removal of the dried prunes from the trays without injury to either fruit or trays caused by sticking, it is necessary to keep the trays clean. It is often necessary to wash them several times in the season.

The relative heights of cars and trays are often sufficiently irregular so that the free air spaces between trays on adjacent cars do not coincide, in which case the air flow between trays may be impeded. Where such a condition exists, it is necessary to place bumpers on both ends of each car so as to separate the stacks of trays by two to four inches and thereby permit unimpeded air flow.

TEMPERATURE

There are four possible systems by which dehydraters may be operated with respect to temperature.

1. *Counter current,* in which the fruit enters at one end of the dehydrater at a relatively low temperature and is advanced intermittently to the other end for finishing at the maximum temperature.

2. *Parallel current,* opposite of counter current, the fruit entering at the highest temperature and finishing at the lowest.

3. *Combination system*, in which the maximum temperature is maintained at the center of the dehydrater and the fruit enters at one end at the lowest temperature, passes through the highest temperature while still only partially dried and finishes at the other end at a medium temperature.

4. *Constant temperature*, in which the fruit is subject to a constant temperature throughout the drying period.

In addition, certain dehydraters combine two or more of the above systems. While each has its advantages, either theoretical or practical, probably none can be considered ideal or perfect.

The counter current system is the one most commonly used on prunes in California, where most air-blast dehydraters are of the tunnel type through which the cars are moved progressively in a direction opposite to that of the heated air.

The parallel current system has not proved satisfactory for prunes and is not used.

Critical Temperature.—Fruit sugars, especially levulose, will gradually caramelize and suffer a loss in weight if subjected to temperatures above 160° F. In fruit that is giving up moisture freely the internal temperature is depressed by the evaporation, as is that of the wet-bulb thermometer, and air temperatures considerably higher than 160° F may be safely used. When the fruit is nearly dry, however, this cooling effect disappears. Both theoretical considerations and practical experience indicate that finishing temperatures in excess of 165° F should not be used. This temperature has been adopted as a standard, for lower temperatures decrease capacity and increase the cost of drying.

Reddish brown rather than black color of the skin may be developed and plump prunes may split and bleed if drying is started at too high temperatures. Good practice indicates that the first temperature in the drying chamber to which prunes are subjected should be between 120° and 140° F.

HUMIDITY

The rate of evaporation from a free water surface decreases with an increase in the relative humidity of the air. However, the cellular structure and syrupy nature of fruit tissues retard evaporation, so that under no condition does the rate of evaporation equal that from a free water surface. When conditions are such that surface evaporation from the tissues exceeds the rate of moisture diffusion to the surface, the surface becomes dry and hard and tends to retard drying. This condition, known as case hardening, can be overcome by reducing the temperature of the air or by increasing the humidity. It is only a temporary condition not necessarily injuring the quality and, since it disappears entirely during the subsequent binning and processing of prunes, it is not to be feared providing the flesh around the pit is sufficiently dried. The maximum rate of drying is attained by using the highest temperature which will not injure the prunes, and sufficient humidity to minimize retarded drying caused by case hardening. In driers employing recirculation the conditions of temperature and humidity may be largely controlled by varying the recirculation. The humidity at the air-outlet end of the drier should not greatly exceed 65 per cent. At the air-inlet end with a temperature of 165° F the relative humidity should not exceed 25 per cent. Higher humidities have been shown to decrease capacity and may injure the quality of the dried prunes. It may be necessary, in very long dehydraters, to reduce the number of cars in the tunnel, thereby increasing the temperature and decreasing the humidity of the air which the prunes encounter on entering the dehydrater.

Considerable trouble has been experienced in some years with dripping of prunes, especially at the cooler end of long dehydraters. This condition is usually due to too high a degree of humidity at the cold end of the drying chamber, which in turn is caused either by inadequate air flow or by maintenance of excessive humidity at the hot end, resulting in an air approaching saturation at the other end of the dehydrater.

The remedy in the first case is to increase the air flow by increasing the speed of the fan. While this will increase the power consumption per hour, the more rapid drying may decrease the power cost per ton. Moreover, the prevention of dripping and sticking will reduce the labor of scraping and washing trays.

The remedy in the second case consists in lowering the humidity throughout the dehydrater by reducing recirculation. When this is done, the prunes will begin to dry soon after entering the dehydrater and dripping will be minimized.

DRYING TIME

The time required to dehydrate prunes properly and thoroughly has been the subject of many exaggerated and misleading statements. The percentages of moisture and sugar in prunes before drying, the size of the prunes, the efficiency of dipping, and the amount of moisture remaining in the dried prunes all affect the drying time. So also do the temperature, humidity, and volume of the air passing through the dehydrater.

Drying times ranging from 20 to 36 hours have been observed in all leading types of dehydraters. In no case has a drying time of less than 20 hours been observed except where partly sun-dried prunes were finished in a dehydrater. Large prunes normally require 28 hours or longer. The average drying time for French prunes is about 24 hours. No dehydrater manufacturer can conscientiously claim a faster drying time, nor should growers use a lower figure in estimating the size of dehydrater required. It is neither fair nor safe to base the capacity of a dehydrater on the exceptionally short time recorded for an occasional car. The average drying time for all cars for the season is the only reliable index of capacity.

STORAGE

Moisture Content.—The proper moisture content at which prunes may be safely removed from the dehydrater and stored must remain a matter of judgment and experience since there is unfortunately no simple, quick, and exact method for determining moisture in prunes. While the same tests commonly used on sun-dried prunes(1) are in part applicable to dehydrated prunes, certain precautions must be observed. When prunes are removed from a dehydrater, they seem moister than they really are because of the softening effect of the heat they still retain. On the other hand case-hardened prunes on cooling seem drier than they really are. It should not be possible to roll the pit freely about under the skin. The pit should be firmly held in the flesh. Prunes containing in excess of 26 per cent moisture will eventually mold. Prunes of such high moisture content will not withstand binning, grading, or processing without injury, and no packing house should receive them. To keep well in bins and to allow for the necessary absorption of moisture during processing, prunes should not be binned with a moisture content in excess of about 20 per cent. The safe moisture content varies somewhat with the size, variety, and sugar content of the prunes, and no exact moisture standard can be given at this time. Operators should not be influenced by the exaggerated claims occasionally made by over-optimistic dehydrater salesmen, but should allow the prunes to remain in the dehydrater until adequately dried, regardless of the time required.

Binning.—No matter how carefully a dehydrater be operated, the prunes removed therefrom will be more or less uneven in their moisture content. Consequently, it is necessary for the prunes to be stored ten days or more to undergo equalization of moisture, commonly termed sweating, before delivery to a packing house.

The prunes should be thoroughly cool before being transferred to a bin. They may be removed from the trays most easily immediately after they have cooled. Poor quality or under-dried prunes should be removed from the trays before the remaining prunes are binned.

Arrangements for transferring the dried fruit from the trays to storage bins vary greatly. The simplest method is to scrape the prunes into rows of lug boxes on the floor, which when filled are carried to nearby bins and emptied. A better scheme is to run a track between the rows of bins, in which case the prunes may be scraped directly from the trays into the bins. In large plants much labor is saved by moving each car of dried prunes up to a hopper into which the trays are scraped, the prunes being distributed to the various bins by an elevator and conveyor as in packing houses. This system is ideal for custom dehydraters where many lots must be binned separately.

In small plants, in order to minimize the number of men employed, it is generally advisable to scrape trays for half the day and dip prunes the other half. In this case it is necessary to restack the emptied trays on trucks standing adjacent to the point where needed for reloading.

Every plant should have sufficient storage space for the entire season's capacity because it may not be either convenient or possible to make packing house deliveries before the drying season is over. It is well to turn the prunes after they have been in the bin for a week or two. If a layer of under-dried or moldy prunes is revealed, they should be carefully removed to avoid mixture with the remaining prunes.

SUMMARY OF OPERATING METHODS

In conclusion, the following summary of steps in the dehydration of prunes may be considered as the present standard based on years of cumulative experience:

1. Lye dip as soon after harvesting as possible and rinse in fresh water.

2. Load the trays fully and uniformly.

3. Enter in cooler end of air-blast dehydrater at 120° F to 140° F.

4. Finish at a temperature not exceeding 165° F and a humidity not exceeding 25 per cent.

5. Store the thoroughly dried prunes in bins for at least two weeks before delivery to packing house, turning if examination reveals inadequate equalization.

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