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# DRYING CUT FRUITS

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## FOREWORD

The use of sulfur dioxide in preparing fruits for drying has been the subject of much controversy and discussion and this bulletin is an attempt to bring together the best available information, as a progress report. It has been for many years and still remains a matter of active investigation at this station and by other governmental as well as commercial agencies. During the past ten years the work at this station has been in charge of the authors, first Christie, and later Nichols. In these studies much of the actual field and laboratory work has been carried out by E. H. Guthier and B. E. Lesley, formerly Assistants in Fruit Products, and by H. M. Reed, now Assistant in Fruit Products. The authors take this opportunity of expressing grateful acknowledgment to them.

Acknowledgments are also due to Frank D. Merrill, Inspector for the apple drier operators of California, for much helpful comment and information on apple drying; and to R. S. Hiltner, Technologist for the Dried Fruit Association of California, for comments and information on sulfuring practices.

# DRYING CUT FRUITS<sup>1</sup>

P. F. NICHOLS<sup>2</sup> AND A. W. CHRISTIE<sup>3</sup>

## INTRODUCTION

For the discussion of California fruit drying, it is convenient to divide the fruits into two groups: first, those which are dried whole, chiefly prunes, grapes and figs; and second, those which are cut before drying, chiefly apples, apricots, peaches, and pears. It is the purpose of this publication to describe in some detail the principles and methods used in the drying of cut fruits. In tables 1 and 2 are summarized the production and disposition of these fruits in the United States and in California.

TABLE 1

PRODUCTION AND UTILIZATION OF APPLES, APRICOTS, PEACHES AND PEARS;  
AVERAGE FOR 1923-1927\*

Fruit	United States production (fresh basis), tons	California				
		Production		Per cent of California crop		
		Fresh basis, tons	Per cent of U. S. production	Canned	Dried	Fresh
Apples.....	4,127,278	194,512	4.7	0†	34.6	65.4
Apricots.....	184,600	177,200	96.0	23.7	66.9	9.4
Peaches.....	1,233,360‡	427,392‡	34.6	52.7	28.9	18.4
Pears.....	505,265	173,950	34.4	25.2	10.3	64.5

\* Compiled by S. W. Shear, Division of Agricultural Economics, University of California.

|| Shipped fresh out of California or consumed within the state.

† Probably less than one per cent; none reported by the Cannery League of California since 1923.

‡ Harvested only.

The cut dried fruits fall much below the uncut dried fruits in tonnage, value and domestic per capita consumption. Raisins and prunes normally constitute over four-fifths of the tonnage and two-thirds of the value of the dried fruit produced in California. The average annual per capita consumption of prunes and of raisins in the United States for 1923-1927 has been 1.56 and 3.60 pounds,

<sup>1</sup> Supersedes Bulletins 330 and 337 of this Experiment Station, in so far as they concern the dehydration of cut fruits; also those parts of Bulletin 388 which pertain to the sulfuring of cut fruits for drying.

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respectively.<sup>4</sup> Nevertheless, the drying of cut fruits is of great importance, since it permits inexpensive conversion of a notable amount of the fruit into relatively imperishable form and assists in stabilizing prices.

TABLE 2

UNITED STATES PRODUCTION, CONSUMPTION, AND EXPORT OF DRIED APPLES, APRICOTS, PEACHES AND PEARS; AVERAGE, 1923-1927\*

Fruit	California production		United States production				
	Dry tons	Per cent of U. S. production	Production, dry tons	Exports		Consumption	
				Dry tons	Per cent of production	Dry tons	Per capita, pounds
Apples.....	8,420	39.3	21,420	12,884	60.1	8,536	0.15
Apricots.....	21,560	100.0	21,560	11,179	51.8	10,381	0.18
Peaches.....	22,500	100.0	22,500	3,451	15.4	19,049	0.33
Pears.....	3,268	100.0	3,268	2,500†	76.5	768†	0.01

\* Compiled by S. W. Shear, Division of Agricultural Economics, University of California.

† Estimated.

Preservation implies the protection of a perishable commodity against agents by which it would otherwise be deteriorated or spoiled. The agents concerned in the spoiling of dried fruits are bacteria, yeasts, molds, insects, enzymes, and probably also certain purely chemical reactions not well understood. For successful preservation, treatments are required that kill or inactivate these agents and prolong the usefulness of the product for the necessary period. Bacteria, yeasts and molds which are everywhere present, multiply and live in the fruit which they decompose in the course of their life processes. The rapidity and extent of the decomposition is largely proportional to the growth and multiplication of these minute plants. Their growth and reproduction is dependent upon the presence of food substances of suitable nature and variety, together with sufficient moisture to keep the concentration of dissolved substances low enough for their use. Fruits contain the necessary substances in abundance and drying merely removes moisture to the point where the concentration of substances dissolved in the water becomes so great as to prevent the growth of bacteria, yeasts, and molds. Presumably the high concentration of soluble substances causes the organisms to shrink or plasmolyze, in which condition they are incapable of normal growth and multiplication or injurious activity. The mere presence of the organisms is not injurious. Reduction of the moisture content of the fruit to 20 or 25 per cent effectively checks their growth.

<sup>4</sup> Compiled by S. W. Shear.

There are three principal methods used commercially for the preservation of fruits by drying: *Sun-drying*, drying by solar heat; *evaporation*, drying by artificial heat circulated by natural draft; *dehydration*, drying by artificial heat circulated by mechanical draft. Any of these methods, properly applied, will preserve the fruit perfectly against bacteria, yeasts, and molds.

The elimination of spoilage by insects is not so easily accomplished by drying. Bees and hornets do not attack dried fruits as they do fresh fruits, nor do ants attack dried fruits so readily. On the other hand, certain insects such as the Indian-meal moth (*Plodia interpunctella* Hbn.), the dried-fruit beetle (*Carpophilus hemipterus* L.), the dried-fruit mite (*Carpoglyphus passularum* Hering), and the saw-toothed grain beetle (*Oryzaephilus surinamensis* L.), attack the dried product. It has been shown<sup>(5)5</sup> that the Indian-meal moth and dried fruit beetle are somewhat inhibited when the moisture content is below 12 per cent or above 24 per cent, but in the normal range of moisture content of dried fruits these insects must be guarded against by exclusion, storage temperature, or fumigation.

Deterioration by enzymes or by purely chemical reactions, while much slower in dried than in fresh fruit, is difficult if not impossible to avoid altogether. Such deterioration decreases with decrease in moisture content, but retardation of this form of spoilage for the necessary period of six months to one year or longer by reduction of moisture content alone requires so low a moisture content as to be impractical commercially. In the case of cut fruits a chemical preservative, sulfur dioxide, is employed. The manner of using sulfur dioxide and the extent to which it is absorbed by the fruit are among the most important problems in the drying of cut fruits. Extensive consideration in this bulletin is therefore given to the need of sulfur dioxide and the best known methods of application and control.

#### THE CUTTING OF FRUITS FOR DRYING

In the preparation of fruits for drying, cutting serves several purposes:

1. It permits the drying of large fruits which have a thick or impervious skin and which would decompose or darken at the center if dried whole.
2. It exposes more surface for drying, making drying more rapid.
3. It exposes surface not protected by skin.

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<sup>5</sup> Reference figures in parentheses refer to publications given in the terminal bibliography.

4. It permits more careful inspection, sorting, and trimming of the fruit.

5. It removes inedible pits or cores, thus increasing the food value of the product.

6. The dried product is more attractive and more easily prepared for the table.

7. It permits the accumulation of pits (fig. 1) or cores for the manufacture of valuable by-products.

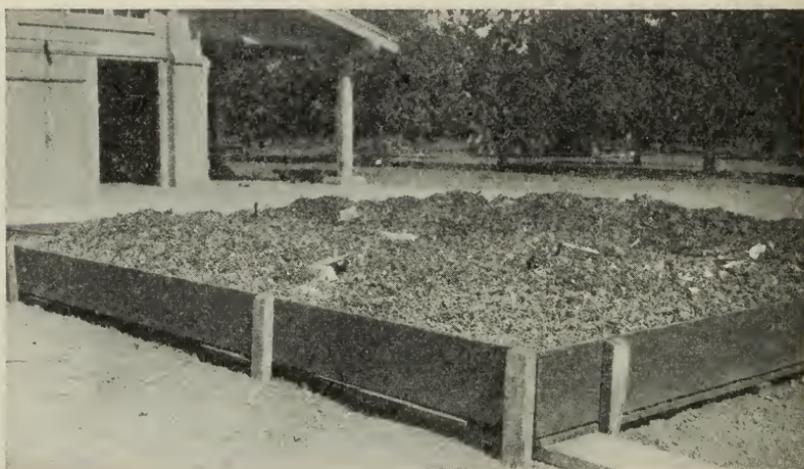


Fig. 1.—Sun-drying apricot pits removed in cutting the fruit.

While cutting has the advantages enumerated above, it increases the susceptibility of the fruit to three types of spoilage during drying and storage:

1. During the drying of these fruits deterioration of color is very rapid.

2. Darkening by oxidation or oxidase action is most rapid on cut surfaces.

3. Cut surfaces are especially attractive to microorganisms and insects.

Failure to give the fruit after cutting and before drying some pretreatment for the purpose of preventing these types of spoilage, results in all cases in an unattractive, unappetizing and unsalable product of scant resemblance to the original fruit in either color or flavor.

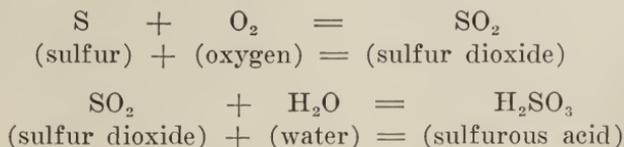
### PRETREATMENTS EMPLOYED

Treatments with steam or brine are fairly successful in preventing deterioration during drying, especially if drying be rapid as in dehydration. The use of brine has little if any effect upon the drying time, whereas the use of steam hastens drying.

The limitations of steam and brine treatments are: first, they require employment of dehydration in order to avoid darkening, fermentation, or attack by insects during drying; and second, they fail to preserve a satisfactory color for the necessary period of at least six months to one year without reducing the moisture content excessively from the commercial point of view.<sup>(5)</sup> Reduction of the moisture content to 10 per cent or below, as is required for the preservation of even reasonably satisfactory color, is not commercially feasible for several reasons:

1. It increases the time and expense of drying far out of proportion to the additional amount of water removed.
2. The extension of the drying period is almost certain to result in darkening the product.
3. Moisture will be reabsorbed from the air in sufficient amount to permit darkening unless the fruit is packed in expensive moisture proof containers such as friction-top cans, sealed cans, or sealed glass jars.
4. The loss of weight resulting from the removal of the additional moisture increases the price or decreases the return for the fruit.
5. The product is less suitable for consumption in the raw state and requires longer soaking for cooking.

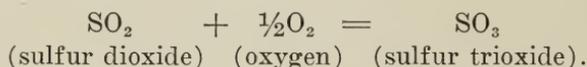
Years of scientific investigations and practical trials have so far failed to reveal any other pretreatment agent as good as sulfur dioxide for the preservation of color in cut, dried fruits. Sulfur has been used for this and similar purposes since ancient times. When burned in air it combines with the oxygen of the air to form sulfur dioxide, a colorless gas. This can be illustrated as follows:



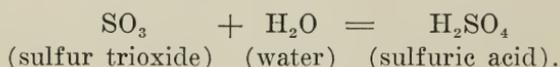
The end product is a mild acid closely related to sulfuric acid but with which it should not be confused. Sulfurous acid is a preserva-

tive used in numerous food products. This acid, and the salts (the sulfites) it forms by chemical reactions, are reducing (oxygen-removing) substances and it is to this property that the preservative action is probably due.

The relationship between sulfurous and sulfuric acids may best be shown by other simple chemical equations. Sulfur dioxide combines with oxygen to form sulfur trioxide:



This reaction normally takes place only slowly, but may be hastened by the presence of certain other substances. When sulfur trioxide dissolves in water, sulfuric acid is formed as:



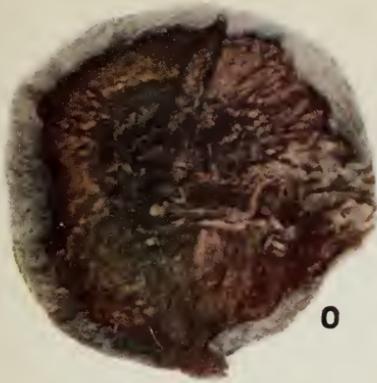
Sulfuric acid and the salts it forms (the sulfates) are not reducing substances and are not ordinarily considered as preservatives. If concentrated, sulfuric acid chars organic matter.

#### THE USE OF SULFUR DIOXIDE IN FRUIT DRYING

By authority of the Federal Food and Drugs Act of 1906, the United States Department of Agriculture is charged with the formulation and enforcement of regulations governing, among other things, the use of preservatives in foods. The Act specifically states that a food must not "contain any added poisonous or other added deleterious ingredient which may render such article injurious to health." In accordance with the provisions of the Act, the U. S. Department of Agriculture carefully investigated the use and toxicity of sulfur dioxide. The conclusions drawn from these investigations have never been published, but the Secretary of Agriculture subsequently issued Food Inspection Decision No. 89 which states that pending determination by the referee board of the wholesomeness or unwholesomeness of this substance, its use will be allowed under the following restrictions:

"No objection will be made to foods which contain the ordinary quantities of sulfur dioxide if the fact that such foods have been so prepared is plainly stated upon the label of each package.

"An abnormal quantity of sulfur dioxide placed in food for the purpose of marketing an excessive moisture content will be regarded as fraudulent adulteration and will be proceeded against accordingly."



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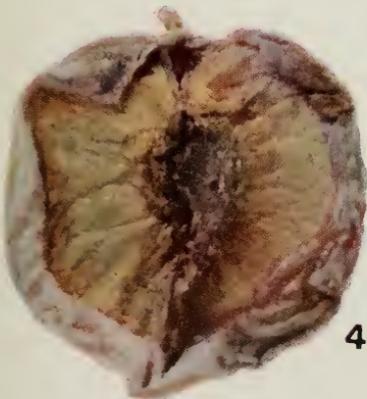
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N

Plate I.—The effect of sulfuring on the appearance of sun-dried peaches (soon after drying). The specimens were selected as typical of lots sulfured as follows: 0, unsulfured; 1, sulfured one hour; 2, sulfured two hours; 3, sulfured three hours; 4, sulfured four hours; N, sulfured overnight.



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The Federal Government therefore permits the use of this preservative though it cautions against its excessive use. So far as is known it has never been demonstrated that the ordinary amounts of sulfur dioxide consumed in dried fruits are injurious to the human system. Without sulfur dioxide, dried cut fruits in the present well-known, attractive and stable form can not be produced.

In addition to complying with the regulations of the United States government, dried fruit must also conform to the regulations of the individual states and the foreign countries to which it is shipped. The present existing maximum limits for sulfur dioxide are as follows:

Country or state	P. p. m. <sup>a</sup>
Canada.....	2500
Switzerland, New York.....	2000
England.....	2000 (750 for raisins)
Germany, Austria, Hungary.....	1250
Czecho-Slovakia.....	1250 (raisins only)
France.....	1000
Japan.....	1000 (apricots; none allowed in other fruits)
New Hampshire.....	None

<sup>a</sup>"P. p. m." means parts per million, or milligrams per kilogram. 1000 p. p. m. equals 1/10 of 1 per cent.

It is important to both packer and grower that the sulfur dioxide content of California dried fruit be kept as low as is consistent with satisfactory color and keeping quality. Failure to do this may prevent the sale of the product or may result in expensive return shipment or condemnation and loss of the fruit.

The darkening of cut fruits referred to above, is not fully understood. These fruits contain substances that are darkened by oxidation which in this case is considered to be chemical combination with oxygen. The fruits also normally contain substances known as enzymes, among which are some called oxidases. These have the property of bringing about or hastening oxidation and darkening. The exact nature of the substances darkened or of the manner in which the darkening is brought about is not entirely clear. The oxidases are known to be inactivated by certain agents<sup>(6)</sup> among which are reducing agents such as sulfur dioxide or sulfurous acid. Also as long as such a powerful reducing agent as sulfurous acid is present it prevents at least to any large extent the absorption of oxygen by the fruit substances which might become darkened. Oxygen may be made available by oxidases or may come from other sources. There is reason to doubt whether all darkening in dried fruit results solely from the activity of oxidases, for products which presumably have been so treated as to destroy or permanently inactivate such enzymes have been observed to darken on prolonged storage.

Sulfur dioxide also prevents spoilage by inhibiting the growth of microorganisms and resulting fermentation or molding and by repelling insects during drying. Either of these agents might destroy the food value or salability of the fruit if not checked.

Sulfur dioxide hastens sun-drying by plasmolyzing the fruit cells, destroying the water-retentive power of the cell walls, and allowing the moisture in the tissues to escape more readily. However, this does not seem to affect the rate of sun-drying in proportion to the amount of  $\text{SO}_2$  absorbed.

Investigations of recent years have emphasized the importance of vitamins in the diet. Fruits, in addition to their appetizing qualities and energy values, are one of the chief sources of vitamins. Very recent studies by Morgan and Field<sup>(7, 8)</sup> indicate that dried fruit which has been sulfured before drying retains a much greater portion of the vitamins of the fresh fruit than does fruit which has not been sulfured. It seems possible that, as a result of this work, eventually a minimum requirement rather than a maximum tolerance for sulfur dioxide may be enforced.

*Sulfur and Sulfur Houses.*—As may be seen from the above paragraphs, the purpose of “sulfuring” or applying sulfur dioxide to the fruit is to make the fruit absorb not only sufficient sulfur dioxide to preserve it prior to and during drying but also to persist during the necessary period of storage. The sulfur dioxide is almost universally applied by exposing the freshly cut fruit to the fumes of burning sulfur in a sulfur house. There are several factors which influence the absorption of sulfur dioxide by fruit. Among them the most important are the concentration of sulfur dioxide in the sulfur house, the condition of the fruit, the time of exposure, and the temperature.

The concentration of sulfur dioxide in the sulfuring chamber is controlled by the quantity of sulfur burned, the rapidity and completeness of combustion, the volume of space and quantity of fruit in the sulfuring chamber, and the loss of sulfur dioxide from the chamber through ventilators or leaks. Loss of fumes from the chamber is influenced by wind velocity and direction.

The temperature affects the absorption of sulfur dioxide in several ways. As the temperature rises the solubility of sulfur dioxide in water decreases. On the other hand increase in temperature increases the rate of reaction or combination of the sulfur dioxide with other substances in the fruit. Also high temperatures presumably soften the fruit tissues and facilitate the absorption and penetration of sulfur dioxide. The general belief is that increasing the temperature increases the absorption rate.

The condition of the fruit has an important bearing on sulfur dioxide absorption. The kind of fruit largely determines the absorption and retention. For example, under ordinary conditions apricots and peaches will absorb and retain much more sulfur dioxide than will apples and pears. The kind of fruit by its influence on the size and shape of the pieces also largely determines the ratio between volume of these pieces and the surface area exposed to the fumes, and therefore, the rapidity of absorption. The composition of the fruit, which varies with the kind and to some extent with the variety, maturity, and locality where grown, presumably also affects the absorption and retention of sulfur dioxide through variations in the amounts of substances with which the sulfur dioxide may react or combine. The surface condition of the fruit is an important factor. This is affected by the interval between cutting and sulfuring and by such treatments as sprinkling with water or lye dipping. If sprinkling is done, care must be taken to use only clean trays in order to avoid washing dirt on to fruit on trays below. As long as the concentration of sulfur dioxide in the sulfur house is greater than that in the fruit the amount absorbed is naturally greater as the time of exposure is increased. Concentration of sulfur dioxide and therefore the time required is influenced by the rate of combustion of the sulfur. The rate of absorption decreases as the amount in the fruit increases and as the concentration of sulfur dioxide in the atmosphere of the sulfuring chamber decreases by absorption and loss. The number of factors influencing absorption of sulfur dioxide by fruit makes it very difficult to control absorption or to illustrate the effect of any single factor by means of simple field tests.

Any type or brand of sulfur is satisfactory for sulfuring fruit, provided it is free from arsenic and oil and will burn freely. It is important to store sulfur in a dry place to prevent absorption of moisture. If difficulty of combustion is experienced the addition of one pound of powdered sodium nitrate (Chile salt peter) to each twenty pounds of sulfur is helpful. Flowers of sulfur usually burn more readily than does lump sulfur. The latter usually requires the use of sets of superposed pans to retain some of the heat of combustion, or other special arrangements in order to secure successful burning. The lump sulfur costs only about half as much as flowers of sulfur. However, the expenditure for sulfur is not usually more than two or three per cent of the cost of drying, and most growers prefer to use the more expensive flowers of sulfur.

While special types of sulfuring equipment located indoors are sometimes used for apples (fig. 15), most of the apples and all of the

apricots, peaches, and pears dried in California are sulfured in small chambers or sulfur houses built out of doors. To avoid annoyance to workers in the cutting shed or dry yard, the sulfur houses should be constructed so that prevailing winds will blow fumes away from and not toward the cutters. It is also important to place the sulfur houses so that the prevailing winds blow towards but never away from the draft intake. As ordinarily constructed, sulfur houses contain enough air to accomplish the combustion of the necessary two

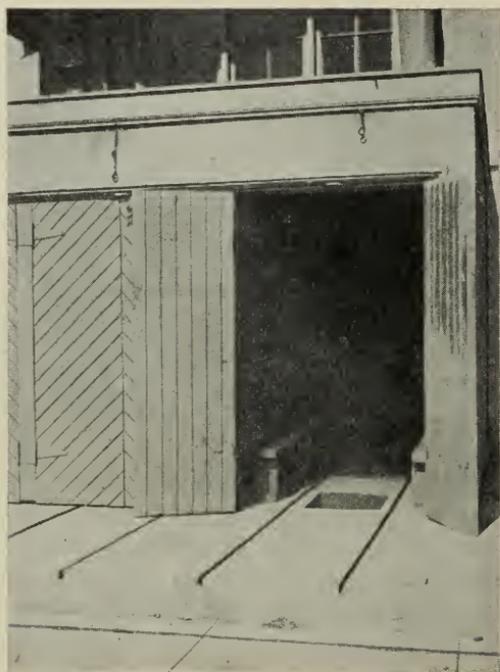


Fig. 2.—A well built group of concrete sulfur houses with close-fitting wooden doors.

to three pounds of sulfur per ton of fresh fruit, provided all the oxygen of the air be consumed in the combustion. However not all the oxygen present in the atmosphere is used in the process of combustion, since combustion ceases when the concentration of oxygen in the air becomes low. This requires definite provision of draft to secure rapid and complete combustion unless the sulfur house is very leaky, in which case more sulfur must be used. In order to secure uniform distribution of the sulfur dioxide the vents should be so located as to cause the current of air and fumes to pass over as much of the fruit as possible. The arrangements shown in figures 4 and 5 have given good results.

The sulfur houses should be so built as to conserve the heat which may be absorbed from the sun and that which is given off by the combustion of the sulfur. At the same time care must be taken that the sulfur is not burned so close beside or under the fruit that scorching will take place. The materials employed in the construction of sulfur houses are concrete, brick, hollow tile, wood, sheet metal, and paper. Houses built of the first three materials are relatively permanent, fireproof, and may be made fairly tight (fig. 2). On the other hand they are considerably more expensive to build than are wooden houses and are generally lower in temperature. Wooden sulfur houses are the most common type (fig. 3). Unless they are

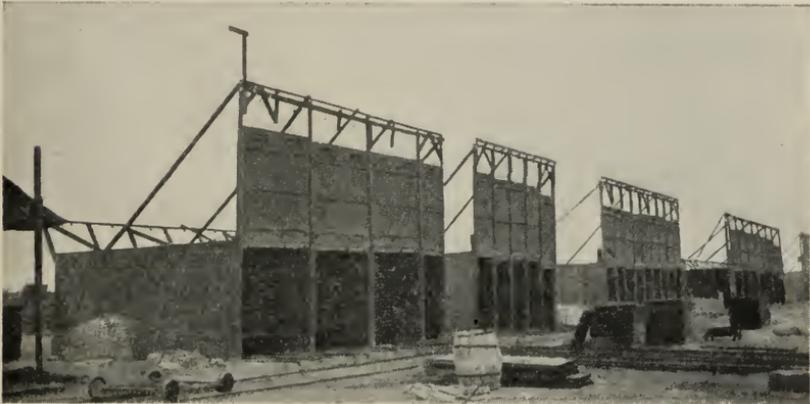


Fig. 3.—A battery of wooden sulfur houses. Note trays, and transfer car in foreground. The doors of such houses are often leaky, requiring props to hold them against the door frames.

carefully built and kept in good repair, they become very leaky and are always subject to fire hazard. However, the use of outside sulfur stoves connected with the houses by properly insulated pipes practically eliminates fire risk. Houses built of flat sheet metal painted black to assist in the absorption of solar heat have been recommended but they corrode badly in spite of any of the protective paints tried so far. Observations have shown that while wood and metal houses reach higher temperatures during the day than do concrete houses, the night temperatures in the concrete houses are higher. From the standpoint of temperature, therefore, the choice of construction material would depend upon whether it is intended to sulfur fruit principally during the day or during the night.

Hoods of paper on a wooden frame may be used temporarily or during emergencies. The fire hazard of these hoods is naturally very great and they are leaky and short-lived.

In designing a sulfur house the size should not exceed that required to hold two trucks of staggered trays—preferably one truck (as in fig. 4) if 3 by 8 foot trays are used—in order to secure satisfactory

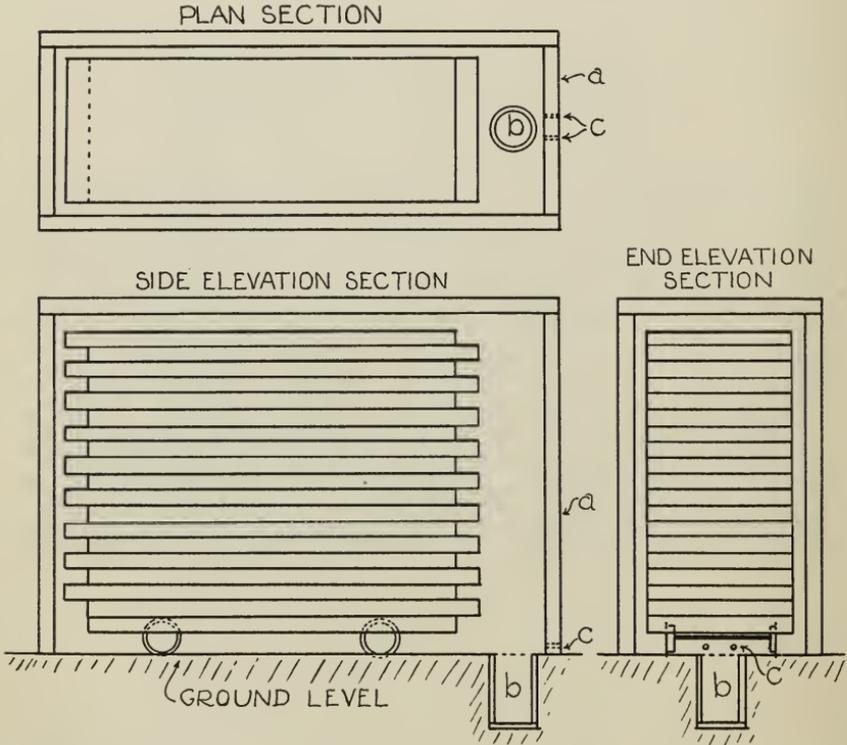


Fig. 4.—Diagram of a simple sulfur house. (a) door; (b) sulfur pit; (c) draft holes.

distribution of the fumes among the trays. The length should be sufficient to provide a free space of at least six inches more than the diameter of the sulfur pan, pit, or flue if this be in the floor. Provision should be made to keep the trays from entering this free space in order to stimulate a rapid rise of sulfur fumes and to cause the necessary circulation as well as to prevent scorching or fire losses. A stove outside the sulfur house has the advantage that it is free from fire risk, and may be inspected readily (fig. 5, I). If a pit is used inside the house, a 12-inch half-length of concrete irrigation pipe

makes a very satisfactory shell when set so that the top comes flush with the sulfur house floor. Where the soil is very dry a similar length of 85 per cent magnesia steam pipe insulation may be used (fig. 4). A concrete, brick or magnesia floor should be provided and the bottom and sides protected from moisture by the use of oil or tar. Difficulty in getting the sulfur to burn rapidly and completely may usually be overcome by employing a slight forced draft produced by a central fan and distributed to the individual sulfur houses by means of a system of pipes one inch or more in diameter (fig. 5, II). Since the most common leakage from a sulfur house occurs around the doors this leakage is used by some operators as a vent, and the stove or pit for burning the sulfur is placed at the opposite end of the house

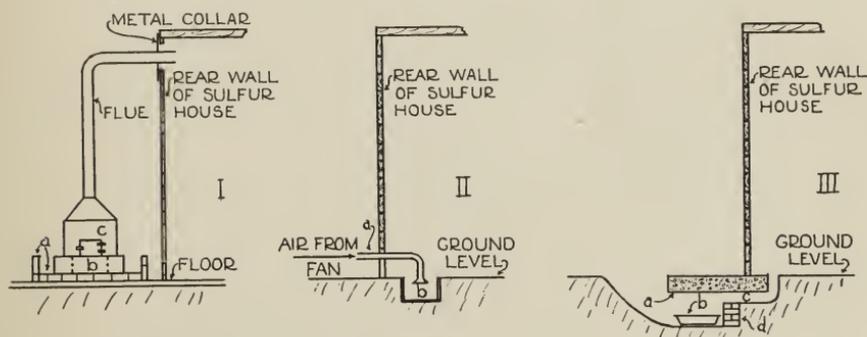


Fig. 5.—Successful types of sulfur burners. I. Stove outside sulfur house; (a) safety pan of metal or brick; (b) sulfur pot; (c) metal stove. II. Sulfur pit inside house with forced draft; (a) pipe from fan; (b) sulfur pit. III. Sulfur pit outside house; (a) tile or concrete pit support; (b) sulfur pan; (c) tile or metal flue pipe; (d) supporting bricks.

(fig. 5). Successful results have also been obtained by placing the sulfur pit in the floor near the door and boring one or two one-inch holes in the bottom of the door (fig. 4).

Whatever the design or the material used in building the sulfur house, it is important that it be tight and carefully built, with close-fitting doors. Only in this way can the combustion of the sulfur be controlled by the drafts or vents provided. A leaky house is subject to great variations in both the concentration of sulfur dioxide in the house, and in the amount of sulfur required for adequate sulfuring. It is wasteful of sulfur and is likely to produce wide variations in the amount of sulfur dioxide absorbed by the fruit.

## DATA FROM SULFURING EXPERIMENTS

The results of some of the experiments made during recent years in the Fruit Products Laboratory may illustrate points which have been discussed above in connection with the preparation and pretreatment of cut fruits for drying.

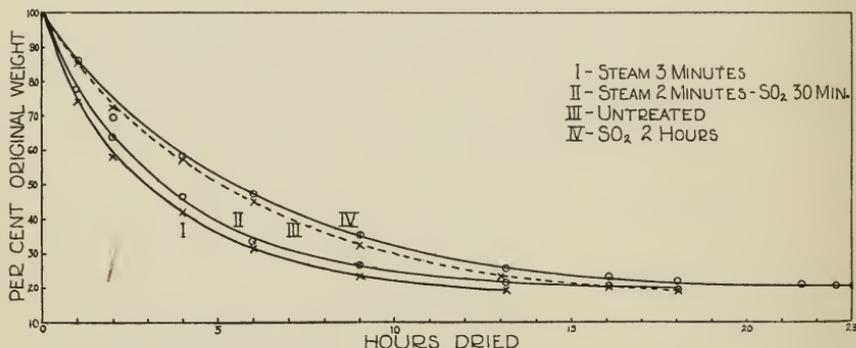


Fig. 6.—Effect of sulfur dioxide and steam on the drying time of dehydrated apricots.

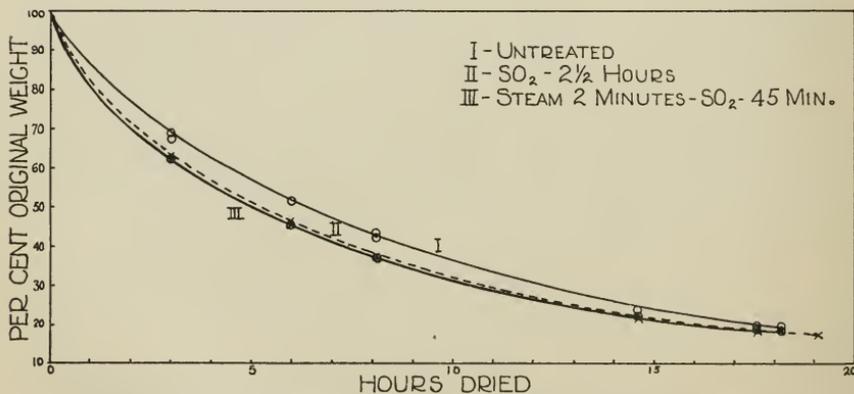


Fig. 7.—Effect of sulfur dioxide and steam on the drying time of dehydrated peaches.

*Effect of Preparation and Pretreatment on the Drying Time.*—That steam treatment shortens the time required for dehydration is shown by figures 6 and 7, but no distinct nor consistent effect of sulfuring appears. As shown by figure 8, however, sulfuring shortened the time required for sun-drying. In the experiments which furnished the data for figure 8, it was noted that while the sulfured samples always dried faster than the unsulfured ones the samples in each series sulfured for different lengths of time and containing varying amounts of sulfur

dioxide, could not be differentiated with respect to drying rate. The marked effect of peeling on the time required for the dehydration of halved pears is shown in figure 9.

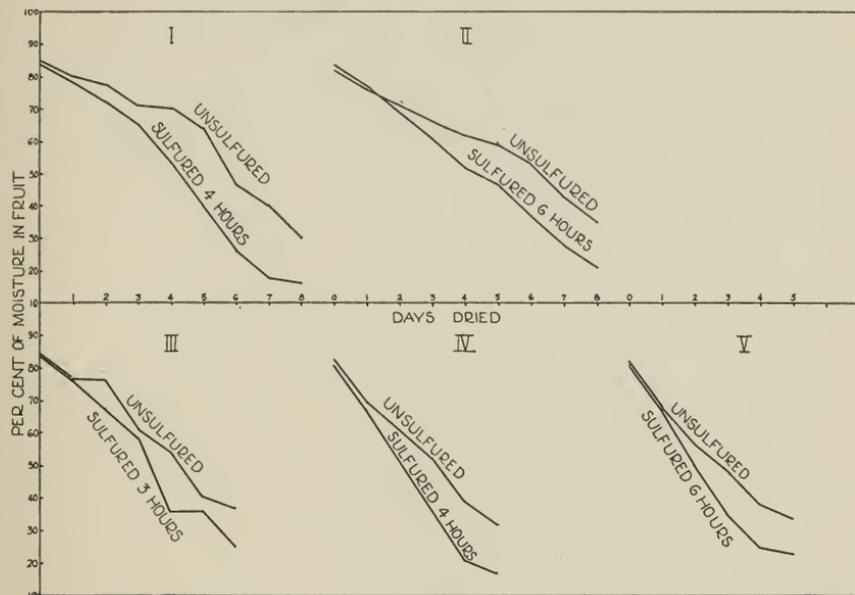


Fig. 8.—The decline of moisture content in sulfured and in unsulfured fruit during sun-drying. I and II, peaches. III, IV and V, apricots.

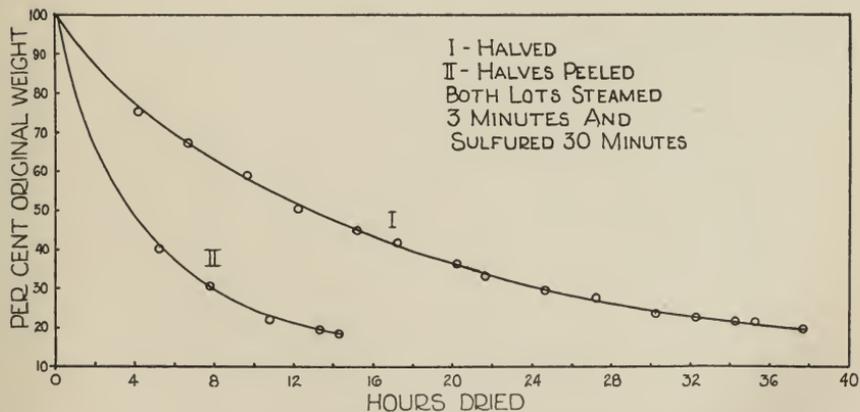


Fig. 9.—Effect of peeling on the dehydration time of pears.

*Effect of Sulfur Dioxide on Color of Dried Fruits.*—Plates I and II indicate the failure of unsulfured fruit to retain the color of the fresh or of the sulfured fruit. These plates reproduce the color of specimens of dried fruit from the experiments on which table 3 is based.

*Effect of Preparatory Treatments on Absorption of Sulfur Dioxide.*

—Numerous experiments have shown that sprinkling fruit with cold water or brine does not increase the absorption of sulfur dioxide. In

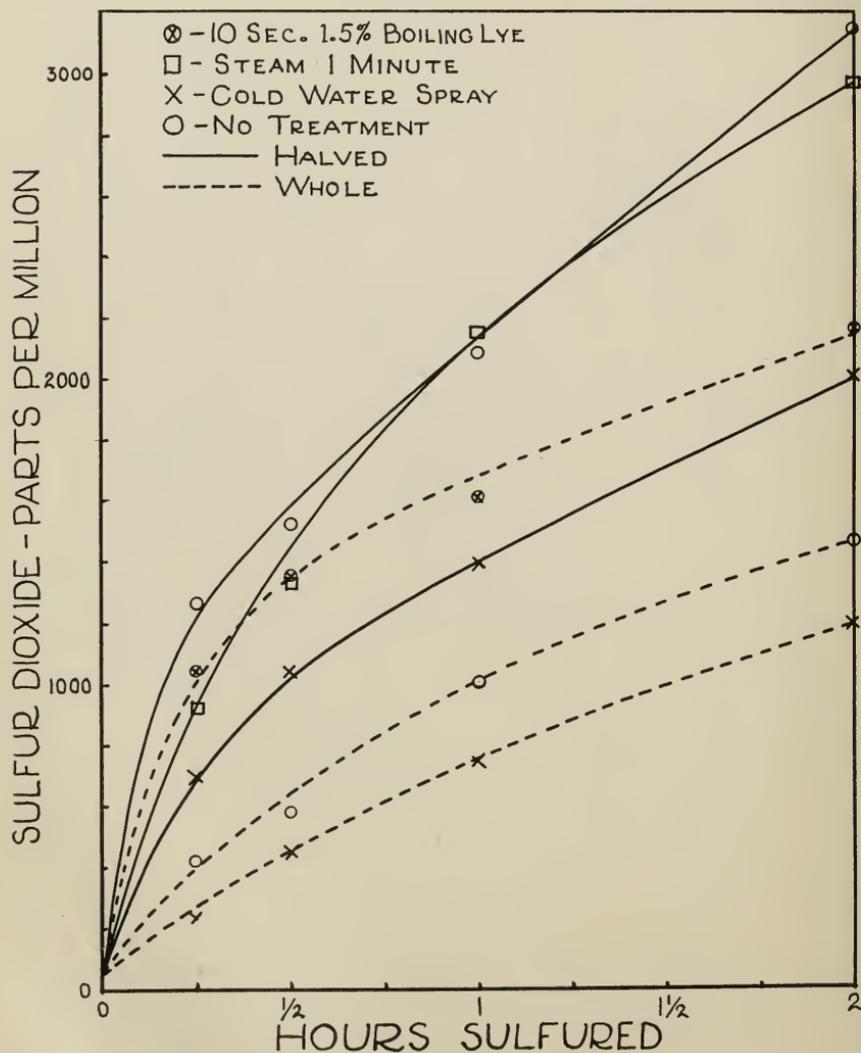


Fig. 10.—Effect of preparatory treatment on absorption of sulfur dioxide by apricots.

figure 10 are given the results of experiments in which sprinkling with cold water just before sulfuring actually decreased absorption. On the other hand hot lye treatment before sulfuring considerably increased the absorption of sulfur dioxide by whole apricots.

*Effect of Concentration of Sulfur Dioxide and of Time of Exposure Upon Absorption of Sulfur Dioxide.*—As shown in figure 11, time, the simplest factor to control, does not have consistent effects except in a general way and within a single set of experiments. Some fluctuations are of course caused by sampling errors, but this does not entirely explain the discrepancies since curves II and III on peaches, which are distinctly parallel, are based on duplicate samples. In the experiments from which these two curves were drawn the sulfur was exhausted in the burner at the end of 3 hours, when more was added.

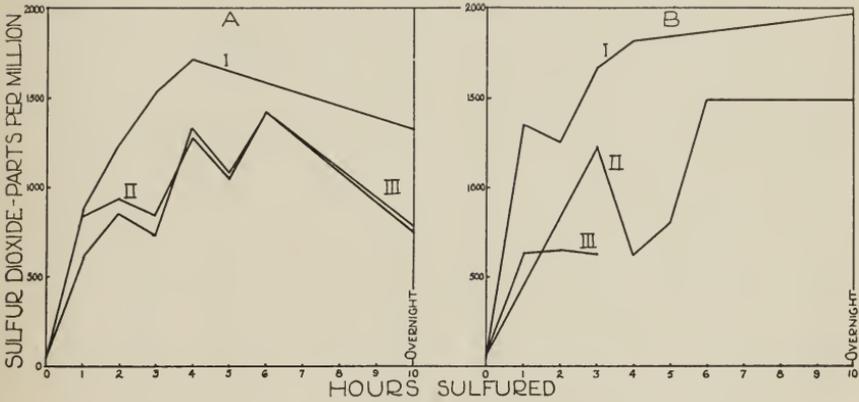


Fig. 11.—Effect of time of exposure on absorption of sulfur dioxide by (A) peaches and (B) apricots.

*The Retention of Sulfur Dioxide.*—The retention of sulfur dioxide by apricots and peaches during drying and subsequent common storage in paper cartons is shown in table 3. Instead of being concentrated fivefold by drying as are the other solid components of the fruit, the sulfur dioxide content remains at about the same level when no correction is made for the amount of moisture present. Under the conditions of storage used after drying, usually half or more of the sulfur dioxide disappeared in the course of six months. This fact is of practical significance to packing house operators in the control of sulfur dioxide content of dried fruits for various markets.

*Experiments with Apples.*—In order to determine the relationship between methods of preparation, time of sulfuring, and sulfur dioxide content, and between the sulfur dioxide content and the color and keeping quality of apples during drying and storage, apples were sulfured under different commercial conditions and compared after dehydration and storage. The results are given in table 4. While samples 1, 5 and 9, were in the sulfur chamber, the flue leading from

one of the sulfur stoves to the chamber was obstructed and the chamber was leaking excessively. Samples 3, 7 and 11 were dipped in 3 per cent brine for 3 minutes before sulfuring. As the table shows, sulfuring after slicing or quartering resulted in a considerable

TABLE 3  
ABSORPTION AND RETENTION OF SULFUR DIOXIDE BY APRICOTS AND PEACHES

Fruit	Time sulfured	SO <sub>2</sub> , immediately after sulfuring	SO <sub>2</sub> immediately after drying	SO <sub>2</sub> after common storage, 6 months
	<i>Hours</i>	<i>p.p.m.</i>	<i>p.p.m.</i>	<i>p.p.m.</i>
Peaches, sun-dried.....	1	883	744	325
	2	1,245	1,016	508
	3	1,536	1,155	695
	4	1,702	1,357	859
	Overnight	1,325	.....	828
Peaches, sun-dried.....	1	835	611	209
	2	934	848	373
	3	838	902	384
	4	1,277	1,190	510
	5	1,046	1,011	524
	6	1,414	1,510	748
Overnight	762	1,222	774	
Peaches, dehydrated.....	1	605	477	139
	2	845	915	196
	3	733	851	205
	4	1,309	1,731	500
	5	1,078	1,139	459
	6	1,414	1,723	634
Overnight	794	851	355	
Apricots, sun-dried.....	1	630	678	154
	2	643	573	156
	3	634	506	230
Apricots, sun-dried.....	1	410	678	254
	2	819	1,235	442
	3	1,229	1,107	339
	4	624	979	264
	5	800	1,062	445
	6	1,485	1,155	448
Overnight	1,488	1,955	512	
Apricots, sun-dried.....	1	1,370	1,062	474
	2	1,250	1,446	688
	3	1,668	2,035	950
	4	1,805	2,422	1,184
Overnight	1,984	2,013	922	

increase in sulfur dioxide content as compared with sulfuring apples whole for the same periods. The brine dipped apples did not absorb as much sulfur dioxide as the undipped in any case, and were found to be inferior in flavor. Keeping qualities satisfactory for eight months were secured only when the apples after drying contained sulfur dioxide to the amount of at least 200 p.p.m.

In another set of experiments, fresh Newtown Pippin apples were peeled, cored, trimmed and then treated in the following ways:

1. Sliced but not sulfured.
2. Dipped whole in 0.5 per cent sulfur dioxide solution for one minute, then sliced.
3. Sliced and then exposed to fumes of burning sulfur for 1½ hours.
4. Dipped as in (2); then treated as in (3).

TABLE 4

EFFECT OF SULFURING METHOD ON SULFUR DIOXIDE CONTENT AND QUALITY OF DEHYDRATED APPLES

Sample No.	Form in which sulfured	Hours sulfured	Form in which dried	SO <sub>2</sub> , p.p.m. in dried apples	Relative quality when dried	Relative quality after 6 mos. common storage
1	Whole.....	1*	Slices	0	4th	4th
2	Whole.....	1	Slices	140	2nd	1st
3	Whole.....	1†	Slices	50	3rd	3rd
4	Whole.....	1½	Slices	210	1st	2nd
5	Sliced.....	1*	Slices	100	4th	4th
6	Sliced.....	1	Slices	220	3rd	3rd
7	Sliced.....	1†	Slices	200	2nd	1st
8	Sliced.....	1½	Slices	250	1st	2nd
9	Quarters.....	1*	Quarters	60	4th	4th
10	Quarters.....	1	Quarters	230	2nd	3rd
11	Quarters.....	1†	Quarters	170	3rd	2nd
12	Quarters.....	1½	Quarters	280	1st	1st

\* Low concentration of sulfur dioxide in sulfur box.

† Before sulfuring, dipped in 3 per cent brine 3 minutes.

The fruit was then dehydrated in a laboratory air-blast dehydrator under temperature, humidity, and air flow conditions closely resembling those used commercially, the drying time being 11 hours. When calculated to a moisture basis of 22 per cent the sulfur dioxide content was as follows: unsulfured, 37 p.p.m.; dipped only, 57 p.p.m.; fumes only, 90 p.p.m.; dip and fumes, 80 p.p.m.

From these results it may be seen that, as has been noted with other fruits, apples dried without being sulfured contain reducing substances reacting in the determination like sulfur dioxide equivalent to between 25 and 50 p.p.m. In other words, unless the sulfur dioxide content reported from analysis exceeds 50 p.p.m. it is doubtful whether any has been retained from the treatment given. The experiments also show that dipping whole apples in 0.5 per cent sulfur dioxide solution for one minute increases the sulfur dioxide content but very little as compared with exposing to fumes of burning sulfur for one

and one-fourth hours. The brief dipping in dilute sulfurous acid solution before exposing to fumes merely forestalls darkening before sulfuring. It does not increase and may decrease the quantity of sulfur dioxide retained after drying.

In another set of experiments<sup>7</sup> cubed apples were exposed to the fumes of burning sulfur for periods ranging from five minutes to twenty-four hours. The dried fruit when analysed contained sulfur dioxide ranging only between 23 and 259 parts per million on the dry basis. This is the equivalent of from 0.001 to 0.013 per cent expressed as sulfur. The amount of sulfur dioxide retained as such is therefore not large even when the time of exposure to sulfur dioxide fumes is increased to about eighteen times the maximum period used in commercial practice. On the other hand the total amount of sulfur present, reported as sulfur, increased from 0.093 to 1.026 per cent as shown in figure 12, the increase amounting to seventy-two times the maximum quantity of sulfur retained in the form of sulfur dioxide. From this it appears that the sulfur dioxide absorbed beyond a maximum of approximately 250 p.p.m. was converted by oxidation into something else, presumably to sulfur trioxide.

A comparison of the total sulfur on the dry basis with the moisture content of the sample when analyzed (shown in figure 12) suggests that there may be a reciprocal relationship between the moisture content of the dried fruit and the extent of the conversion of the sulfur dioxide to some other compound. The relation is somewhat irregular, however, and may have no significance. In the presence of water, sulfur trioxide becomes sulfuric acid according to the reaction:  $\text{SO}_3 + \text{H}_2\text{O} = \text{H}_2\text{SO}_4$ . While this was not actually demonstrated, it was observed that the fruit, after sulfuring for 6 or more hours but before drying, was progressively blackened. This is a characteristic effect of strong sulfuric acid, but it is doubtful whether the concentration of sulfuric acid present in these samples was great enough to cause the blackening by charring action. More probably it was due to changes in the plant pigments.

In another set of experiments concerning the shipment and storage of dried apples, a lot of fruit containing 145 parts of sulfur dioxide per million when packed, was divided into two portions. One portion was held at Berkeley from September when it was packed, until the following February. During this time the other portion was shipped by steamer from San Francisco to New York and return via the Panama Canal. The content of sulfur dioxide in the fruit held at

<sup>7</sup> Conducted by C. E. Mangels, C. R. Gross, and P. F. Nichols, Commercial Dehydration Laboratory, Bureau of Chemistry, U. S. Department of Agriculture (1921).

Berkeley averaged 68 p.p.m. at the end of the period. That of the portion shipped and returned had fallen to an average of 31 p.p.m., within the range of "blank" determinations on sulfured fruits. The color of the fruit held in Berkeley showed no deterioration while that shipped had darkened badly.

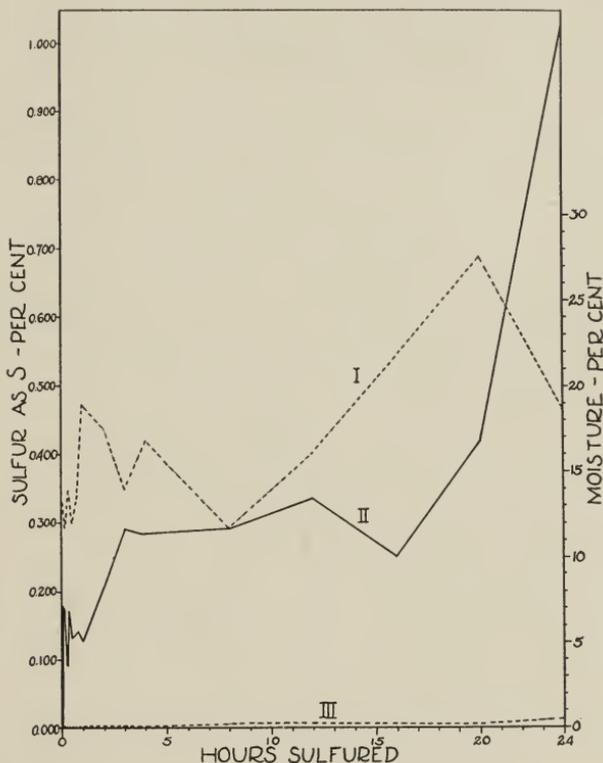


Fig. 12.—Effect of time of exposure on the sulfur content of dehydrated cubed apples. I, moisture as dried; II, total sulfur, dry basis; III, sulfur dioxide as S, dry basis.

#### COMPARISON OF THE THREE METHODS OF DRYING

In discussing the comparative merits of sun-drying, evaporation, and dehydration, it is convenient to consider apples separately from apricots, peaches, and pears because apples are never sun dried on a commercial scale and they are extensively dried by the process generally referred to as evaporation. Apricots, peaches, and pears on the other hand are sun dried almost exclusively, and almost never evaporated. The comparisons therefore are practically limited to the evap-

oration and dehydration of apples and to sun-drying and dehydration of apricots, peaches, and pears.

*Methods Used for Apples.*—Apples are never sun-dried on a commercial scale chiefly because apples mature late, when climatic conditions are unfavorable to sun-drying, and because they are easily injured in appearance by dirt and dust which naturally accompany sun-drying. Since apples are not processed or otherwise treated for packing in such a way as to remove this dirt the injury would be more serious.

The principal types of evaporators used in drying apples are the stack, the kiln, and the Oregon tunnel. These have been fully described by Caldwell.<sup>(1)</sup>

All natural draft driers have high fuel costs resulting both from crude construction and the excessive discharge of air required to secure even reasonably satisfactory air flow. Many evaporators, especially those of the stack type, also involve inefficient employment and high cost of labor. The uneven drying characteristic of the type requires much shifting of trays and sorting of under-dried fruit from fully dried fruit on the trays. Because of the physical nature of the fruit and the established trade standards apples may be dried in kiln evaporators which permit both fair economy of labor and satisfactory quality. Stack and Oregon tunnel evaporators are inefficient both as to fuel and labor and have no particular merit so far as quality is concerned. Wiegand and Powers<sup>(11, 12, 13)</sup> have shown the inefficiency of the Oregon tunnel and have suggested forced draft as a means for its improvement. This simply converts it into a dehydrater.

As used in connection with fruit drying, dehydration implies the evaporation of moisture by artificial heat applied through the medium of air the flow of which is mechanically produced by fans. The employment of forced draft permits a large measure of control of the distribution, the temperature, and the relative humidity of the air in the drying chamber. Whether built primarily for apples or for other fruits, dehydraters operated in accord with the requirements for this fruit have proved efficient and economical when used for apples and yield a product of high and uniform quality with comparative freedom from operating and sorting troubles. New dehydraters built for apples in recent years have practically always been modern and efficient types. They are tending to displace the old evaporators, especially in the Pacific Northwest.

When evaporation and dehydration are properly carried out, the products are practically indistinguishable as far as quality and yield are concerned. The shrinkage in weight necessarily involved in dry-

ing is the same with either method. Commercial standards of quality in dried apples are concerned chiefly with the care given to the preparation of the fruit for drying. Therefore, the product is judged on uniformity of size and freedom from blemishes, foreign matter, cores, skins, and screenings. The excellence and uniformity of color is the only characteristic of quality which is affected by the method of drying and even in that case, as will be shown later, pretreatment is more important than the method of drying. With evaporators, however, the proper accomplishment of drying is more difficult, often resulting in injury by over-heating or over-drying portions of the product which have become sufficiently dry sooner than other portions as a result of lack of uniform distribution of air currents. Such injury reduces either quality or yield, quality being sustained only by sorting which reduces the yield and increases the cost. Dehydration reduces or entirely eliminates such difficulties.

An idea of the operating costs of dehydration may be gained by examination of table 5, the figures in which were obtained by a study of five plants.

TABLE 5  
COST OF DEHYDRATING AND PACKING APPLES

Item	Unit, average	Cost per gross fresh ton		
		Maximum	Average	Minimum
Labor.....	17.3 man hours.....	\$8.37	\$6.54	\$5.17
Fuel.....	18.5 gallons.....	1.15	.79	.37
Power and light.....	41.3 kw-hr.....	1.70	.99	.41
Sulfur.....	2.8 pounds.....	.15	.09	.04
Boxes.....	6.5 boxes.....	1.62	1.52	1.33
Total operating cost.....		\$11.21	\$9.93	\$8.33

Accurate cost figures on evaporators have not been secured but estimates reported range from \$60 to \$90 a dry ton, equivalent to \$8.57 to \$12.85 or an average of \$10.64 per fresh ton at a shrinkage of 7 to 1.

*Methods Used With Apricots, Peaches, and Pears.*—There is an extensive commercial demand for sun-dried apricots, peaches and pears, but not for the dehydrated as such. It follows, therefore, that for any dehydrated product to find a ready market, it must resemble the sun-dried product so closely that it is difficult or impossible to distinguish between them. This result is not always obtainable. However, in many cases it is possible by employing special pretreatment and handling methods to secure a dehydrated product which so closely

resembles the sun-dried product that it will be acceptable to the trade. Of the three fruits, it is probably most difficult to produce dehydrated pears of sun-dried appearance. Moreover, apricots and peaches are ordinarily dried so early in the season that there is no danger of loss of the crop and no increase involved in the drying cost because of weather hazard. These facts have naturally limited both the interest in the dehydration of these fruits and its utility. These fruits are, therefore, almost exclusively sun-dried. Evaporation is never used for drying these fruits in California and dehydration is used only in plants built for other fruits.

Fruit which is dehydrated may of course be dried from the fresh to the dry state entirely within the dehydrater. More commonly, however, it is first exposed to sun for one or more days before being placed in the dehydrater. Another special treatment developed during the last year or two is that of allowing the fruit to stand a day or more on trays on trucks in the plant or on an outdoor side track but without direct exposure to the sun. The result of these methods of handling is to bring about the changes in color that accompany sun-drying. The use of these methods involves some additional expense. In the first case, extra handling is required to spread the trays in the sun and subsequently to restack them on trucks. In the second case, sufficient extra equipment of trays and trucks is needed to hold an amount of fruit equal to the capacity of the drier for one or more days. Consequently dehydration is not employed except for some special reason such as an attempt to reduce the sulfur dioxide content or to release sun-drying equipment sooner than would be possible if drying were completed in the sun.

*Special Products.*—The dehydration of apricots and of peeled peaches and pears gives a dried product that, after cooking, closely resembles the cooked fresh fruit. The market being unfamiliar with the differences between these products and those which are sun-dried, the cost and difficulty of selling them is increased and they may bring a lower instead of a higher price. Also peeling the fruit increases cost and shrinkage. These facts have so far prevented any great increase in the manufacture of these special products. Several fairly large and apparently adequately financed companies have attempted to manufacture and sell a varied line of dehydrated products including these fruits. Whether because of inefficient production and selling methods or general difficulties of finance and management, these companies have so far proved unsuccessful.

In table 6 the operating costs of dehydrating are compared with those of sun-drying apricots, peaches, and pears. According to the

figures given the cost of dehydration is about double that of sun-drying in the case of apricots and pears and about 50 per cent greater in the case of peaches. The dehydration costs for apricots and pears were obtained several years ago on plants that would not now be considered strictly modern, and may therefore be somewhat high. However, the dehydration costs for peaches include some instances in which the fruit had first been partially dried in the sun, with resultant lower costs; there are also included instances in which the peaches were peeled.

TABLE 6

## COSTS OF DEHYDRATING AND SUN-DRYING APRICOTS, PEACHES, AND PEARS

Item of cost	Apricots		Peaches		Pears	
	Dehydrated (1 plant)	Sun-dried* (average, 6 growers)	Dehydrated (average, 6 plants)	Sun-dried* (average, 4 growers)	Dehydrated (average, 2 plants)	Sun-dried* (average, several growers)
Labor.....	\$21.30	\$9.83	\$9.49	\$7.88	\$15.13	\$10.60
Fuel.....	.92		1.09		4.14	
Power and light.....	.73		.81		1.98	
Sulfur.....	.57	.35	.42	.42	.68	.48
Lye.....			(when used) .66			
Total operating cost per fresh ton.....	\$23.52	\$10.18	\$12.04	\$8.30	\$22.26	\$11.08

\* From Christie and Barnard.<sup>(5)</sup>

Because of the facts enumerated above and because of the great variability of treatment of the fruit before dehydration, particularly partial sun-drying, it is impossible to make a strict comparison of the costs. Nevertheless the indications are that for these fruits the operating costs of dehydration may be expected to be greater than those of sun-drying. In addition, the fixed charges for interest, depreciation, taxes, and insurance may be expected to be greater unless the dehydration plant is operated on a larger tonnage and for a longer season than is possible in the employment of sun-drying equipment.

## THE DRYING OF APPLES

Dried apples are, unlike the other dried fruits discussed in this publication, always a by-product. They are dried as a means of saving a portion of the crop which can not be marketed profitably in the fresh condition. Ordinarily the fruit used for drying is of low grade. Supply and demand of both fresh and dried fruit determine largely the amount and grades of fruit dried.

Apples are produced in larger quantity and over a wider area than any other tree fruit. Partly on this account, and partly because they keep well for months in cold storage they are available in fresh condition throughout the year. The quantity placed in storage is influenced by the size of the crop and both these factors influence the quality and price of the fruit available for drying. To a large extent the price of the dried fruit is controlled by the quantity produced and sometimes also by the carryover.

Of the domestic consumption of dried apples about 90 per cent are said<sup>8</sup> to go to ship's stores, camps, the Army and Navy, and restaurants, hotels, and pie factories. Thus only 5 per cent of the total production is sold through retail stores. Marketing is highly competitive as to price, and buyers are chiefly large users whose routine methods require a material that is uniform in quality and available throughout the year.

The material for drying is available over a longer period than is the case with the other fruits under discussion. Operating seasons of 120 days or more are common. If as sometimes happens, the early season production of dried apples is small, the price high, and the total production of apples is large, apples can be removed from cold storage, dried, and sold at a profit. In seasons when the total production is not exceptionally large but the proportion of off-grade fruit is high, there are often large increases in the production of dried apples. Almost always, however, this results in serious depression of the price.

*Localities, Varieties, and Quality.*—Nearly two-thirds of the apples dried in California are produced in a district centering at Watsonville in Santa Cruz and Monterey counties. Most of the remainder is produced in the Sebastopol area in Sonoma County where in some seasons as much as 50 per cent of the crop is dried.<sup>(10)</sup> San Bernardino County is the third in importance. While there are about one hundred driers in Sonoma County and only thirty in Santa Cruz County the Sonoma County driers are smaller than those of Santa Cruz County, having an average capacity only about one-sixth as great.

Certain general considerations influence the selection of varieties for drying. The shape should be regular and smooth to minimize labor and loss in peeling and trimming. The texture should be firm, both to reduce preparation losses and to give the best possible appearance to the finished product. The color of the skin is an important consideration since it has a direct effect upon efficiency in preparation. Yellow or green skin is preferred since traces of skin left on the fruit do not

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<sup>8</sup> Personal communication from F. D. Merrill.

mar its appearance as do traces of red skin. The color of the flesh may be either white or yellowish since trade preference on this point is divided.

The Newtown Pippin, the best pie variety, is the one most extensively dried in California. The Gravenstein and the Bellflower, ranking next in quantity dried, are considered better for sauce. The Pearmain, Jonathan, Wagener, Hoover, and Rhode Island Greening are also dried. It cannot be too strongly emphasized that the varieties should not be mixed. Different varieties require different times to cook and the color of the flesh varies considerably so that mixing reduces the uniformity of appearance so desirable in the dried product.

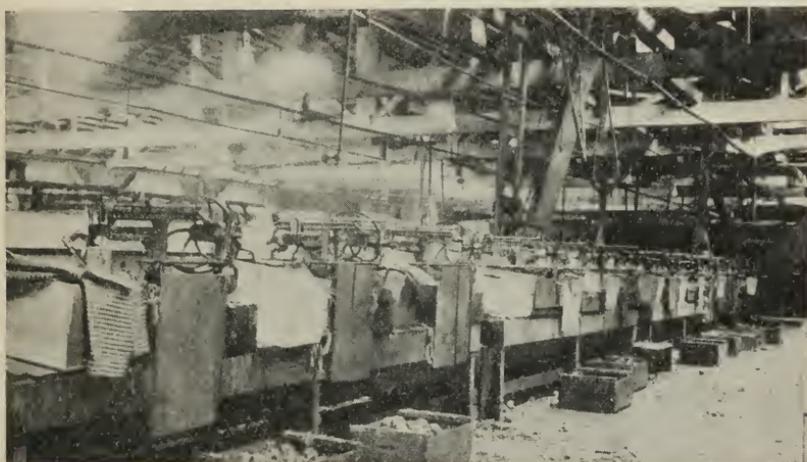


Fig. 13.—A battery of apple peeling machines.

The quality of the fruit used for drying is usually "B" or "C" grade that on account of size or external blemishes cannot profitably be sold fresh. Such apples when properly prepared yield an entirely sound and wholesome dried product. Windfalls are used to a considerable extent for choice and standard grades. The fruit should be handled carefully because bruises produce brown spots in the finished product in spite of careful peeling, coring, trimming and sulfuring. Grading for size permits greater efficiency in peeling and better uniformity in drying but the practice is not universal and is probably not profitable unless the size variation is considerable.

*Preparation of Apples for Drying.*—Peeling and coring is always done by machines (fig. 13) which may be either hand or power operated. Hand operated machines are generally considered preferable for beginners. Experienced operators may accomplish more

with power driven machines, but beginners are likely to injure the fruit, especially by improper coring, on such machines. Power machines should be so timed as to permit a maximum output while still affording time for proper placement of the fruit in the machine. The proper speed is generally at the rate of about thirty apples a minute.

Peeling machines require constant care and frequent adjustment for the size of the apples being peeled in order to secure good work. One or more spare machines should be available in every plant to be used in case of breakdown. The chief necessity for care and skill in operation is in centering the fruit on the machine in such a way that the coring knife follows the line of and surrounds the core thus minimizing trimming labor and loss.

However carefully peeling and coring may be done, the fruit always requires some extra trimming. This can best be done as the fruit passes slowly along an inspection belt, preferably before slicing. Slicing in the machine at the time of coring gives a higher proportion of perfect rings than when it is done later, but it complicates trimming and often results in incomplete removal of bits of core, seeds, and skin, thus reducing the quality of the product.

Cores, peels, and trimmings usually amount to approximately 20 per cent of the fresh gross weight, but this varies with the size and condition of the fruit. In a large drying center these may ordinarily be sold to a nearby vinegar factory for from \$1 to \$3 a ton at the drying plant. Such material would be of perhaps greater value for pectin manufacture, but apple pectin is not manufactured commercially in California. The use of the waste for edible products may be complicated by the presence of arsenic in excess of the amounts permitted by the food and drug authorities, as discussed elsewhere in this bulletin.

Cutting is best and most commonly done after the peeled and cored fruit has been trimmed. Quarters, sixths, and eighths are preferred for export trade. They are obtained by forcing the cored, peeled, and trimmed apples through a die in which are set radial knives. This method of cutting gives pieces of uniform size. It also permits a heavier load per square foot on trays when used for drying. A load of three or four pounds of quartered fruit per square foot is as readily handled and sulfured as two or three pounds of slices. While the drying time is increased, the additional load may result in increased drying capacity for a given plant. Dehydrated apples are sometimes cubed. In this form they are readily sulfured and dried. The finished product has attractive and uniform appearance and cooks

readily. Some additional cost is involved in the cubing operation and in the screening out of fine pieces resulting from the cubing process. This additional cost, together with the consumer's unfamiliarity with the product has accounted for the fact that so far the cubed product has not been consistently profitable, and its production is not increasing.

No trays are used in kiln evaporators but the fruit is conveyed by means of wheelbarrows or trucks from the slicer or sulfur box to the kiln floor. In other types of driers, trays are loaded from slicer, inspection belt, or sulfur box. The size most commonly used is 3 by 3 feet. In a few instances 3 by 4 feet or 3 by 6 feet are used. The use of wire screen trays (fig. 14) is being discouraged on account of the



Fig. 14.—Wire screen trays.

objection of buyers to marks and the presence of zinc which usually accompanies the use of such trays. Oil may be applied to reduce marking and corrosion but does not entirely prevent it.

About 90 per cent of the tray driers now use the slat-bottomed tray (figures 17 and 18). Such a tray does not mark nor flavor the fruit. It is fairly light, inexpensive, and durable if the frame is rigid and the slats are not too small. The preferred width for the slats is about  $\frac{3}{4}$  inch. Except in the stack evaporators and Oregon tunnel driers, where cleats or guides are provided to support the trays, the trays are of the self-supporting type, the sides of them being sufficiently high to provide adequate free space over the fruit and below the tray above. For apple drying it is especially important that sufficient free cross-sectional area be provided between trays on account of the relatively large volumes of air required.

*Sulfuring Apples for Drying.*—Sulfuring may be done either before or after the peeled, cored, and trimmed apples are sliced, quartered, or cubed. The advantages of sulfuring before cutting are that the tendency for the fruit to darken is more quickly arrested and that since whole apples do not pack together, sulfuring may be more uniform than it is in sliced and heavily piled fruit. It has the disadvantages that the fresh surfaces exposed by subsequent cutting are somewhat more susceptible to oxidation and darkening and that it is more unpleasant to the workers in the plant to cut the fruit, after, rather than before sulfuring. Sulfuring after cutting, if the fruit is quartered or cubed, permits more uniform sulfuring. Some driers dip the fruit in 2 per cent salt solution immediately after peeling to

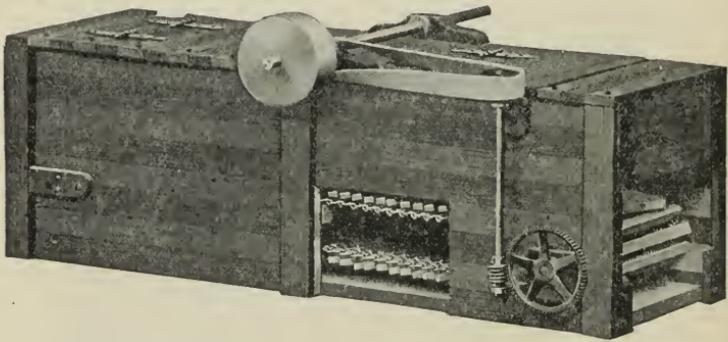


Fig. 15.—A continuous sulfur box of the type used for apples.  
(Courtesy, Boutell Mfg. Co.)

prevent discoloration before sulfuring. Some convey the fruit for 10–15 minutes through a bath of  $1\frac{1}{2}$  to 2 per cent sodium sulfite solution in place of sulfur smoke, though the latter is almost universally preferred.

If the fruit is sulfured before cutting, it is best done on moving wooden-slat belt conveyors passing through a sulfur chamber (fig. 15). The length of the sulfuring period is determined by the length of the chamber and the speed of the belt. The fumes of burning sulfur are introduced from a stove placed outside the chamber. In such cases, where the sulfur burns continuously, crude or lump sulfur is fully as satisfactory as sublimed flowers of sulfur, since sufficient heat is easily maintained. It is best to have the fumes pass through the chamber in a direction opposite to that of the fruit. To control the flow of fumes it is desirable to use forced draft. The fumes should enter the chamber several feet from the end at which the fruit is discharged from the

belt and flexible doors or baffles should be provided at the loading and unloading ends to prevent the escape of fumes.

When the fruit is sulfured after cutting, it is exposed to the fumes on trays in an ordinary sulfur house. The sulfur is burned in pans, pots, or pits as previously described.

The quantity of sulfur used per gross fresh ton of fruit ranges from one and one-half to five pounds. This is equivalent to from 1.9 to 6.25 pounds per prepared fresh ton or from 10.5 to 35 pounds per dry ton. The quantities of sulfur used in the two types of sulfur chambers vary through approximately the same range. The smaller amounts are adequate if the fumes are not wasted through leaks.

Apples never contain sulfur dioxide in excess of the the legal maximum. In fact the chief difficulty in sulfuring apples is to make them absorb and retain sufficient to preserve their color during storage. The higher the sulfur dioxide content the better will be the color and keeping quality after drying and during storage. The periods of sulfur treatments used in commercial practice vary from 20 minutes to one and one-half hours. The texture does not break down from exposure to sulfuring as does that of apricots and peaches. The sulfur dioxide content of apples declines rather rapidly during drying and prolonged storage, and may finally disappear.

It is customary to pack dried apples with a moisture content as close as possible to the legal limit. The Federal standard is 24 per cent, while that of the Dried Fruit Association of California is 22 per cent as a maximum. As indicated, the amount of sulfur dioxide required to maintain a satisfactory color increases with the amount of moisture present. At 24 per cent moisture under certain storage conditions, dried apples may ferment or mold unless enough sulfur dioxide is present to prevent it. Re-sulfuring the fruit after drying, though sometimes done, is not a common practice. It is, therefore, important that the amount of sulfur dioxide absorbed by the fruit before drying be large enough to maintain an adequate amount during storage. It is considered that in the pretreatment of apples for drying the time of sulfuring should never be less than one hour and may safely be increased to two hours or more.

*The Process of Drying Apples.*—In drying apples in kiln evaporators the fruit is spread on the floor to a depth of about six inches or more if the fruit is in quarters. The temperatures used range from about 150° F in the initial stages of drying to as high as 175° F when the fruit has been in the kiln for approximately half of the time required. In the final stage of drying, temperatures over 160° F are not advisable. Relative humidities in the exhaust air range from 90

per cent at the start to 35 per cent at the end of the drying period. The fruit is usually turned two or three hours after drying has begun and every two hours or oftener thereafter, with final intervals of about  $\frac{1}{2}$  hour. Leaving the fruit undisturbed for the first 5 or 6 hours is said<sup>(1)</sup> to result in a better product with fewer broken rings. The average drying time is about 12 hours.

In drying apples in stack evaporators it is customary to load the trays to a depth of approximately the diameter of the slices. The temperatures and the time required are very similar to those of the kiln evaporator. Instead of turning the fruit with shovels or forks as in the kiln drier to overcome the tendency of the fruit at the bottom of the stack to dry most rapidly, the trays are shifted upward and downward and turned end for end.

In drying apples in dehydraters certain conditions must be present which are not necessary for prunes. While the load of prepared apples per square foot of tray area is very slightly if at all less than that of prunes, the drying time is only about one-half as long and the amount of water to be removed is approximately 35 per cent greater. Therefore the amount of water to be removed per hour is nearly three times as great for apples as for prunes. Since the heat required is directly proportional to the amount of water to be evaporated, the relative size of the burners and area of flues or other heating equipment is relatively greater with respect to spreading area for apples. Similarly, there is a greater drop in temperature of air passing a given distance in contact with the fruit, with a correspondingly greater increase in relative humidity. If the cool end of the drying tunnel is allowed to reach too low a temperature and too high a humidity, drying is greatly retarded. In maintaining a satisfactory drying rate the counter current has been found successful but not the parallel current.

In a tunnel dehydrater built for apples the portion of the tunnel actually used for drying should not exceed 30 feet in length. In a drier built for prunes or other fruits the tunnel should not be loaded with apples beyond that length. To a certain extent, of course, the temperature drop may be decreased by increasing the velocity of the air, and in an apple dehydrater where the reduction of temperature drop is of special importance the highest air velocity consistent with economy should be maintained. This velocity which is considered to be 700 to 800 feet per minute, in addition to reducing temperature drop, has also the advantage of insuring in large measure uniform distribution of the air stream. It should be noted, however, that increasing the air velocity does not decrease the temperature drop proportionately since it also increases the rate of evaporation.

The maximum safe temperature with the counter current air system is 160° to 165° F. For rapid drying, the relative humidity should not exceed 18 to 20 per cent at the hot end.

The physical characteristics of a dehydrater for apples differ from those of a dehydrater of similar daily capacity for prunes. This may be shown by comparing the figures given by Christie<sup>(2)</sup> for a prune dehydrater with approximate figures calculated in a similar manner for apples. The methods used in calculation, together with explanatory material, will be found in other publications.<sup>(2, 4, 9)</sup> The figures for prunes and apples are as follows:

	Prunes <sup>(2)</sup>	Apples
Capacity per 24 hours, gross fresh tons.....	10	10
Capacity per 24 hours, prepared fresh tons.....	10	7.5
Capacity per 24 hours, dry tons.....	4	1.5
Shrinkage in drier.....	2.5 to 1	5 to 1
Load per square foot, pounds.....	3.5	3
Drying time, hours.....	24	12
Spreading area in drier, square feet.....	5,714	2,500
Water evaporated per hour, pounds.....	500	500
Over-all thermal efficiency of plant, per cent.....	45	40
Gallons fuel required per hour.....	8.6	9.7
Air volume required, cu. ft. per min.....	22,532	29,600
Air velocity, feet per minute.....	750	730
Maximum temperature, hot end.....	165	160
Maximum humidity, hot end, per cent.....	25	20
Maximum humidity, cool end, per cent.....	65	65

From the figures above it will be seen that, as compared with prunes,<sup>(2)</sup> a given daily capacity in gross fresh tons of apples may require only half the spreading area or tunnel capacity as will the same tonnage of prunes, but the requirement for heat will be equal and about 25 per cent more air will be required. In other words a tunnel which will operate satisfactorily at full capacity on prunes will be more than doubly overloaded and will fail, if filled with apples. In order to operate successfully on apples it can be loaded to only half or less than half its loading capacity.

#### THE DRYING OF APRICOTS, PEACHES, AND PEARS

Apricots, peaches, and pears are dried in large quantities only in California and are usually sun-dried. Where apricots and peaches are dried it is usually as the principal product and not as a by-product, as with apples. Dried pears, however, are usually a by-product like apples, except in Lake County. Practically all varieties of apricots can be successfully dried, canned, or shipped fresh. Muir and Lovell

are the principal peach varieties used for drying and they are grown almost exclusively for this purpose. In California the Bartlett is the only important pear variety, whether for fresh shipment, canning or drying. Cold storage of fresh fruit is not used in drying, though pears are picked slightly green and allowed to ripen in common storage.

The dried fruit is held in common storage until shipped in "original condition" or processed and resulfured for packing. The quantity of fruit dried and held in storage has a pronounced effect upon the price which it will bring. Where a considerable amount is carried over from one season into the next, the price it will ordinarily bring is much depressed both because such carryovers usually follow a season of large production and because the quality of the fruit in storage has usually deteriorated.

Seasonal variations in the price of these dried fruits does not greatly affect the total production of the fresh fruit, but does influence the proportion of the crop which is dried, particularly that of apricots which can readily be diverted from fresh shipment or canning as the prevailing price may indicate. The prevailing price at the time of harvesting therefore has a direct effect upon the possibility of carry-over and the next season's price.

Among the countries to which these fruits are exported, Germany and the United Kingdom take by far the greatest amount. Naturally the price and conditions of exchange largely influence the destination of dried fruit exports.

Apricots and peaches when picked for drying should be fully mature to produce high and uniform color and maximum yield in dry weight. To avoid the formation of "slabs" from fruit which collapses in cutting and drying, the fruit should be fairly firm. Pears on the other hand, are always picked green and allowed to ripen in boxes. During the ripening process the pears are usually sorted for ripeness at least once (fig. 16). In the course of this sorting they are sometimes also graded by hand for size. Fruit of large size is less expensive to handle and brings a much better price.

*Preparation of Apricots, Peaches, and Pears for Drying.*—The use of arsenical sprays to protect apples and pears from the codling moth during the growing season usually leaves a slight residue containing arsenic on the skin of the fruit. The regulations of the United States and of Great Britain tolerate only a very slight amount of arsenic in foodstuffs. In Great Britain the maximum limit is 0.01 grain of arsenic (as arsenic trioxide,  $As_2O_3$ ) per pound<sup>9</sup> of the

<sup>9</sup> One pound equals 7000 grains.

food. In the United States the present limit is 0.017 grain of arsenic trioxide per pound of fruit, though this limit is likely soon to be reduced to 0.01 grain as in the case of other foods.<sup>10</sup> These regulations are rigidly enforced. As removed from the tree the fruit usually contains on the skin, around the stem, and in the calyx or blossom end of the core, sufficient arsenic to exceed these limits. Before the fruit can be sold for consumption in the fresh state, therefore, some treatment for the removal of spray residue is usually necessary. Under the authority of the Spray Residue Act, the California State Depart-



Fig. 16.—Sorting pears for ripeness before drying.

ment of Agriculture issues rules and regulations which should be consulted by all growers, shippers or packers of either fresh or dried apples or pears.

Since apples are always peeled for drying no difficulty is ordinarily experienced except in using the cores and peelings for edible by-products. Pears, however, are almost always dried without removing the skin, and since drying increases the proportion of arsenic to fruit to about six times that of the fresh fruit before drying, the need for removing the spray residue from fruit to be dried is correspondingly greater. The Dried Fruit Association of California requires that all dried pears sold by its members must, before drying, be carefully wiped or washed in a suitable solvent and have the calyx removed so as to eliminate all spray residue.

<sup>10</sup> Hyde, A. W.—U. S. Dept. of Agriculture administrative decision on spray residues, April 19, 1929.

The most effective method for removing spray residue is that of washing in dilute acid or alkali. The equipment, concentration of acid or alkali, temperature of the bath, and time of exposure are not standardized. In spray washers one-third per cent hydrochloric acid for 30 seconds is usually sufficient, while in basket dippers one-half per cent acid for as much as 3 minutes may be required. A concentration of  $2\frac{1}{2}$  per cent acid has been used without injury to the fruit. The difficulty of securing complete removal of the residue is increased when the temperature of the bath is low or when the fruit is particularly waxy.



Fig. 17.—Cut pears on slat-bottomed trays being stacked on trucks for sulfuring and dehydration.

Usually, apricots, peaches, and pears are not peeled for drying. They are halved and the pits are removed from apricots and peaches. The stems and calyx are removed from pears. Variations are made in manufacturing certain special dehydrated products. For these, peaches and pears may be peeled, pears cored, apricots and clingstone peaches dried whole, or the latter sliced after halving.

It is necessary that considerable care and skill be employed in the cutting of these fruits in order to obtain a dried product of good appearance. Sharp knives must be used and the fruit cut completely around so that the halves may be separated, leaving clean-cut edges. Cutting machines have so far found no acceptance in preparing fruit for drying.

The fruit should be placed on the trays with the cut surface uppermost and without overlapping (fig. 17). When properly loaded the trays will hold approximately two pounds of apricots, three pounds of peaches or three and one-half pounds of pears per square foot. The trays used for drying vary considerably in size and construction. Those used in sun-drying are most commonly 3 by 8 feet or sometimes 3 by 6 feet for apricots and peaches. For dehydration the size of tray used varies. Some plants are equipped with 3 by 3 foot trays and others with 3 by 4, 3 by 6 or 3 by 8 foot trays. In order to permit ready access of the air to the fruit with consequent rapid drying, the bottoms of the trays should be made of slats not more than one inch wide but for strength the slats should not be less than  $\frac{3}{4}$  inch wide and supporting cross braces should be provided. Though they are not so suitable for dehydration, the shake bottom trays used for sun-drying may be modified for this use by removing the end pieces, substituting a flat end brace, and preferably raising the sides. It is very important that openings of ample height are provided for the passage of air through the ends and over the fruit. The alteration of sun-drying trays for use in dehydration is not advisable unless they are in good condition, since they are subjected to much handling.

Nearly all trays are made of wood. Pine is used for both frames and bottoms or spruce for frames where extra strength is desired. New redwood is likely to stain the fruit and is not commonly used for trays.

In stacking trays of fruit for sulfuring, drying, or curing, the sun-drying trays with closed ends are staggered lengthwise to permit  $\text{SO}_2$  fumes and air to enter freely. Since the trays used for dehydration are always open at the ends or sides through which the air passes, staggering is not necessary.

It is important to keep the trays as clean as possible at all times to avoid soiling the fruit and to minimize sticking of the fruit to the trays. Many dry yards and dehydraters are equipped with simple tray washing machines in which water sprays and revolving stiff fiber brushes soften and remove dirt, fruit fragments, and syrup.

*Sulfuring Apricots, Peaches, and Pears for Drying.*—Apricots, peaches, and pears are sulfured in sulfur houses as soon as possible after cutting and traying. In Lake and Mendocino counties it is customary to sprinkle pears with cold water or weak brine before sulfuring, in the belief that it prevents case hardening of the fruit before drying begins and also increases the absorption of  $\text{SO}_2$ . As indicated by the experimental studies reported in figure 10, it is probable that sprinkling retards rather than hastens the absorption of

SO<sub>2</sub>. From this point of view, therefore, sprinkling may be regarded as a means of avoiding excessive sulfuring. The practice is also used to some extent for peaches and apricots. Apricots, peaches, and pears are always sulfured in sulfur houses of the type already described. The quantities of sulfur commonly used range from six to twelve pounds per fresh ton, but three to four pounds are sufficient if the sulfur is used efficiently in a tight house.

Regulating the time of exposure is the principal means of controlling the amount of sulfur dioxide absorbed. To secure and retain satisfactory commercial color apricots and peaches should contain sulfur dioxide to the extent of 1,500 parts per million. Experiments conducted by the Dried Fruit Association of California in the course of several seasons show that satisfactory results are obtained by exposing apricots for two hours or exposing peaches for three hours to dense fumes of sulfur burned by natural draft, provided the house is warm and air-tight except for the minimum necessary drafts. A heavy smoke must be maintained throughout the sulfuring period. By the use of forced draft or special sulfur burning equipment the time required may be reduced to one hour or even less. Sulfuring apricots and peaches for eight hours or over night is not uncommon though it is unnecessary and may be objectionable. Pears are sulfured as long as 72 hours by some operators. When the sulfur is burned by natural draft a sulfuring period of six hours appears to be a minimum for pears for the insurance of satisfactory keeping quality.

*Sun-drying Apricots, Peaches, and Pears.*<sup>11</sup>—Fruit to be sun dried should be spread in the sun as soon as possible after sulfuring has been completed. Apricots and peaches should remain exposed to direct sunshine until they are at least half dried, after which the trays should be stacked in a staggered pile with the open ends in the direction of the prevailing winds. Two to six days sun before stacking are usually required, the total time of drying averaging 7 days for apricots and 8 for peaches. When the weather is not excessively hot, drying may be hastened by omitting the stacking process and permitting the fruit to be exposed to the sun for the entire drying period, though this is done at the risk of injury to the quality. At the time the fruit is scraped from the trays after drying, all discolored pieces and slabs should be sorted out, since it can be done more efficiently at this point than at any later time.

To preserve a light color, pears should be exposed to direct sunshine for only one-half to two days after sulfuring, the time varying

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<sup>11</sup> For detailed information see terminal reference 3.





0



1



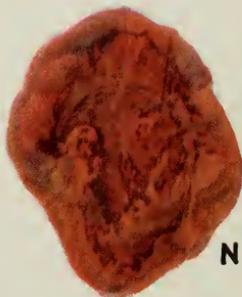
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4



N

Plate II.—The effect of sulfuring on the appearance of sun-dried apricots (soon after drying). The specimens were selected as typical of lots sulfured as follows: 0, unsulfured; 1, sulfured one hour; 2, sulfured two hours; 3, sulfured three hours; 4, sulfured four hours; N, sulfured overnight.

with the intensity of the sun's rays. After this preliminary exposure the trays are stagger-stacked usually with blocks or cross bars laid over each tray to separate it from the one above and thus hasten drying by improving the circulation of air. While stacked it is of course important that the top tray be covered to prevent undue exposure to the sun. Two to four weeks are usually required to complete the drying in the stack and during this time the trays are ordinarily restacked several times to permit the removal of culls or of fruit which is sufficiently dry or conspicuously moist.

*Dehydration of Apricots, Peaches, and Pears.*—Natural draft evaporators are not used in drying apricots, peaches, or pears, and where artificial heat is used modern air-blast dehydraters are employed. There are numerous general considerations affecting the use of dehydraters on these fruits.

*Should Dehydration be Employed for Apricots, Peaches, and Pears?*—At present, unless the question is qualified, the answer must be "no." This is particularly true of the dehydration of the fresh fruit. There are, however, conditions under which dehydration of these fruits may serve a useful purpose and may be distinctly advisable. In cases where sun-drying equipment is available but inadequate, dehydration of the fruit after it has been partially sun-dried will greatly increase the capacity of the dry-yards. Fruit which has been partially dried in the sun and finished in the dehydrater so closely resembles fruit which has been completely dried in the sun that it passes as sun-dried fruit.

If sun-drying facilities are not available, but a dehydrater is at hand, though it may be intended for other fruit, it is probably advisable to use the dehydrater rather than to provide sun-drying facilities. Where it is important to keep the sulfur dioxide content low, a dehydrater may be of especial service since dehydrated fruit requires but very little sulfuring to maintain satisfactory color during drying. However, the experimental evidence does not indicate that more sulfur dioxide is lost from the fruit during dehydration than during sun-drying (table 3). Finally, where there is an existing demand for the special products referred to in another section a dehydrater is, of course, indispensable. However, the development of the market for such products is likely to be expensive and risky.

*Should a Dehydrater be Built Exclusively for the Drying of Apricots, Peaches, and Pears?*—Again, if no qualifications be made, the answer must be in the negative. The sun-dried product is the standard product in the market and thus may be sold most readily. The investment required for sun-drying equipment of a given capacity

is less than that required for dehydration. The cost of sun-drying is generally lower and the risk of rain damage is not great in most districts where these fruits are dried. The only circumstances under which the building of dehydraters for these fruits is justified are, first, when weather conditions are unfavorable for sun-drying as in some of the coast districts, and second, when there appears a definite demand for a special dehydrated product.

Growers desiring dehydraters may build from an original design or from plans and specifications furnished by a dehydration engineer. Or they may buy one from a commercial manufacturer of dehydraters. Building a drier from an original design, unless the builder has had previous experience is likely to result in an inefficient and defective plant. On the other hand, previous experience with successful dehydraters is likely to lead to infringement on one or more of the existing patents covering various features of dehydrater construction. Even if the plant is built from plans and specifications furnished by a dehydration engineer, the grower without experience in building is likely to encounter serious practical difficulties of construction. On this account the issue of dehydrater plans and specifications by the California Agricultural Experiment Station has been discontinued. Also some of the more expensive parts of the dehydrater, such as the motor, fan, furnace parts and trucks must be bought from manufacturers. As compared with buying the plant itself from a manufacturer, therefore, the grower who builds his own plant may save money only in connection with construction labor while he may be unable to secure his materials as cheaply as does the manufacturer. For these reasons it is believed that in nearly all cases the course which will be most satisfactory to the grower in the long run will be to buy a commercially built fireproof dehydrater.

Proper temperature, humidity and air flow are necessary for the successful operation of a dehydrater. In the simplest type, a straight tunnel with counter-current air flow, the following conditions have been found effective. The maximum temperature at the finishing point where the fruit is sufficiently dry should be about 155°–160° F for apricots and peaches and about 140°–150° F for pears. Higher temperatures are dangerous because dry or nearly dry fruit is very susceptible to heat injury. The most desirable relative humidities at the hot end of the tunnel are for apricots approximately 25 per cent, for peaches 30 per cent, and for pears 35 to 40 per cent. The air velocity used should be the maximum consistent with efficiency, generally not less than 500 and not more than 800 feet per minute.

The drying time naturally varies with the temperature, relative humidity, air velocity, load in the drying tunnel, and especially with respect to the extent to which, if at all, the fruit has been previously dried in the sun. Other factors also influence the drying time and it is impossible to give more than an approximate figure. Apricots dried altogether in the dehydrater usually require from 15 to 20 hours; peaches 24 to 30 hours; and pears 30 to 48 hours.

### STORAGE OF CUT FRUIT

The conditions necessary for the successful storage of dried fruits are that the fruit be dried to the proper degree, and that suitable storage facilities be provided.

Excessive drying results in needless loss of weight, and often injures the color of the dried product. In sun-drying it exposes the fruit to possible damage for an unnecessarily long time and in dehydration increases the cost. On the other hand the fruit keeps better during storage if the moisture content is low.

It is difficult to describe clearly the characters of properly dried fruit. Ordinarily, it should not be so dry as to rattle on the trays. It should be firm yet pliable. The skin should not separate on rubbing. When the pressure is released after squeezing a handful tightly together, the individual pieces should spring readily apart and resume nearly, if not quite, their former shape. The difficulty in determining whether the fruit is sufficiently dried is somewhat increased in dehydration, first because of the softening effect of the high temperature at which the fruit leaves the dehydrater, and second because of the case hardening which to some extent always accompanies dehydration. When warm, therefore, because of its softness the fruit appears more moist than it really is; but as soon as it is cool, because of the case-hardening it appears drier. Only first-hand experience can give to an operator good judgment in identifying the proper degree of dryness.

For dried apples offered for sale the maximum moisture content allowed by the U. S. Food, Drug and Insecticide Administration is 24 per cent. The Dried Fruit Association of California allows only 22 per cent. No definite limits are set for other fruits, but the processed fruits usually range in moisture content from 20 to 30 per cent and pears average about 30 per cent. In the natural condition, before processing, dried apples usually contain 18 to 20 per cent and are sprinkled sufficiently to bring the moisture content close to 22 or 24 per cent. Dried apricots and peaches in the natural condition contain from about

10 to 20 per cent while pears have from 20 to 30 per cent. Pears from Lake and Mendocino counties are not usually processed. With the exception of pears that are not to be processed, good practice indicates that when drying is completed the moisture content should be between 15 and 20 per cent in order to allow for the moisture added in processing for packing.

Methods for the determination of moisture in dried fruit are not entirely satisfactory in either accuracy or convenience. Several methods have been proposed and are being used, but each is open to objections of a practical or theoretical nature. Likewise, methods for the determination of sulfur dioxide are in dispute. All these



Fig. 18.—Dehydrated pears being dumped into sweat boxes.

methods are under investigation by various governmental and private agencies, and none can be said to be ideal for purposes of control. Growers or packers who may wish to establish laboratories and do their own control work will be provided with instructions if request is made to the Fruit Products Laboratory, University of California. From what has been said above it will be clear that such instructions cannot at present be considered authoritative or final, although consistent determinations of either moisture or sulfur dioxide may be obtained by constant adherence to any method.

In the packing houses dried fruit is usually stored in bins. However, apples which are undergoing the curing process of sprinkling and turning are stored in piles on an open floor until they are packed in boxes. Dried apricots, peaches, and pears are sometimes held by the growers for more or less extended periods after drying though they

are usually delivered to a packing house within two or three weeks or as soon as curing or "sweating" (equalization of moisture), is sufficiently complete. While this may be done in bins, it is best done in sweat boxes (fig. 18) about 39 by 27 by 8 inches, and holding about 150 pounds of fruit. Delivery of the fruit to the packing house is preferably made in boxes. Sacks are also extensively, if not more commonly, used but may result in curling of flat cut fruits and thus reduce the proportion of large fruit separated by the hole-plate graders.

Storage of the fruit at the ranch, dehydrater, or dry yard should receive as careful attention as at the packing house. To minimize color deterioration and sugaring, the storage place chosen should be as uniformly cool and dry as possible. To prevent infestation by insects and contamination by dirt and dust the storage place should be scrupulously cleaned, protected from winds, and well lighted. From the standpoint of insect infestation, it is especially important that none of the fruit of the previous year be permitted to remain near or even in the same building with the fruit of the current season since old fruit is almost invariably heavily infested. Protection from rodents and other animals is of course necessary.

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