


# Commercial DEHYDRATION of FRUITS and VEGETABLES

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## FOREWORD

The shortage of metal containers and the critical transportation problem have made urgent the need for dehydration of foods for military, lend-lease, and civilian requirements. Present facilities are inadequate. Adaptation of present Oregon fruit driers as well as installation of new dehydration equipment will be necessary to meet the established quotas. Increased production of vegetables to meet dehydration needs is imperative.

Selection of high quality raw materials and the proper preparation and pretreatment of those raw materials for dehydration are as important as the drying procedure in production of high quality dehydrated foods. Inactivation of enzymes by adequate blanching and close control of dehydration temperatures and humidities is required.

With proper attention to preparation methods and to the control of the drying operation, products are obtained that can be stored successfully in appropriate containers. They then will be nutritious and of good flavor and appearance when properly prepared for consumption.

Wm. A. Schoenfeld

Director

# Commercial Dehydration of Fruits and Vegetables

By

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FOOD is as definitely a war essential as are machines and munitions. Transportation of food under war conditions is a large factor in its final utility because it must reach our fighting forces and those of our allies as well as allied civilian populations throughout the world. There is a shortage of metal containers and of shipping space. To relieve this tremendous supply problem, dehydration of foods has been selected as the method of preservation best suited to help cope with these present needs and restrictions. The government estimate of requirements of dehydrated vegetables for 1943 is 400,000,000 pounds. At present only about 120 dehydration plants are in operation. An additional 200 plants will be required in the United States to reach the production capacity needed for satisfaction of the goals set.

In addition to the requirements for military and lend-lease needs, commercial production of dehydrated vegetables for domestic civilian consumption will assume proportions unthought of 2 years ago. To relieve distributional dislocations and to surmount metal container shortage difficulties, more and more dehydrated foods will be finding their place in the daily American diet.

Reduction of bulk and weight, which contribute to the ease of packing and shipping, are factors that should be considered of importance in food preservation for the armed forces. Dehydrating vegetables and fruits by removing water reduces their bulk and weight.

The material decrease in weight varies between 70 and 90 per cent of the original weight of the product. With every shipping facility taxed to its utmost, dehydrated products representing large amounts of food with a minimum of bulk can be transported to make available a greater variety of food for army, navy, and lend-lease.

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## ADAPTABILITY OF DEHYDRATION PLANTS TO THE WAR EFFORT

How can Oregon take its position as a producer of dehydrated vegetables as a part of this nation-wide project? The state has 61 dehydrators of newer design located on farms throughout the Willamette and Umpqua valleys. There are 54 older type dehydrators, which have been remodeled and equipped with fans, that can be adapted to present dehydration procedures. Finally, there are 72 natural-draft driers usable for farm or custom drying of fruits and vegetables. Of those not now suitable for commercial operation, many could be put in condition to satisfy some of the needs that will increase as present food stocks dwindle.

Originally the kiln and stack-type natural drier predominated in Oregon. Gradually through active participation by research workers of the Oregon Agricultural Experiment Station and others on the problems of drying, the Oregon tunnel drier became the type most generally used. These are of both natural and forced draft construction.

In 1919 investigations in this field of work brought out the importance of mechanical recirculation of air. There resulted the adaptation of fans and recirculation to the old tunnel driers and development of new modern dehydrators along similar lines. These newer types are now available for the drying of fruits and vegetables.

Oregon's dehydrating plants, originally designed to meet the needs of the fruit grower, are readily adaptable for drying other products. Most of the better class dehydrating plants have capacities averaging from 20 to 50 tons of potatoes per day.

It is obvious to those acquainted with this industry that drying equipment alone will not be sufficient to adapt the dehydrator to this type of food preservation. When products like potatoes, cabbage, onions, beets, etc., are to be handled, preparation machinery such as blanchers, peelers, slicers, and shredders will be needed. As most canning machinery manufacturers have converted their operations to defense and as only a limited amount of equipment is being manufactured for the canning and drying industry, it can readily be seen that a cooperation of dehydration plants with long-established canneries would be the logical approach to the problem of utilization of our dehydration facilities.

In most of Oregon's fruit-producing areas where dehydrators were originally set up, canneries likewise exist. It is therefore conceivable that organization of dehydrators and canneries into units where one could serve the other would be possible. This would then make the preparation machinery of the canneries available to the dehydration plants.

## OREGON'S VEGETABLE PRODUCTION

By reference to Table 1 it readily can be seen that increased production of vegetables for processing and fresh-market consumption is highly desirable if a worth-while production of dehydrated products is to be achieved under this intensified program.

Table 1. OREGON PRODUCTION OF VEGETABLE CROPS FOR PROCESSING AND MARKET (1942) AND CORRESPONDING POTENTIAL DEHYDRATION TONNAGE

| | Fresh basis | Approximate drying ratio | Dry basis if dehydrated |
|---|---|---|---|
| | *Tons* | | *Tons* |
| Beans (green) | 23,500 | 10 –1 | 2,350 |
| Beets | 8,300 | 10 –1 | 830 |
| Cabbage | 13,000 | 18.5–1 | 684 |
| Carrots | 7,025 | 9 –1 | 780 |
| Celery | 8,460 | 17 –1 | 498 |
| Peas | 40,280 | 5 –1 | 8,060 |
| Onions | 47,500 | 11 –1 | 4,318 |
| Potatoes | 222,000 | 7 –1 | 31,714 |
| Sweet corn | 11,600 | 10 –1 | 1,160 |
| Tomatoes | 7,738 | 21 –1 | 369 |
| Total | 389,403 | .......... | 50,763 |

## ADAPTING PRESENT FACILITIES TO DRYING PROGRAM

The many natural-draft driers in the state are not well suited to commercial drying of vegetables because the heat cannot be controlled and the circulation of the air is too variable. For community and farm use, however, they are usable for conservation of fruits and vegetables. To make them available for this purpose, families should organize in the neighborhood of one of these units and set up facilities to care for blanching and the continuous operation of the drying unit during the harvesting period. When raw products are available in adequate quantities this method of drying would be more efficient than home units and would conserve a large quantity of food material for the civilian population during this emergency.

When most of these dehydrators were built, direct-heat units fired by oil were installed. Such a unit ordinarily would not have sufficient capacity to provide the necessary heat so essential for the drying of the vegetables, because vegetables contain more moisture than fruit. Conversion of these plants to vegetable drying would require the addition of a boiler in each case to provide sufficient steam for blanching and plant sanitation needs. In most dehydration plants, ranging in size from 20 to 50 tons capacity, a boiler of 50 to 100 hp. would be necessary to provide steam for blanching and cleaning only. Conversion of fruit driers to vegetable dehydration may necessitate the installation of larger-capacity oil burners where increased production is desired.

## REQUIREMENTS FOR COMMERCIAL DEHYDRATION

The question naturally arises, how can entrance into the vegetable dehydration field be accomplished? Since one of the primary objectives of dehydration is the conservation of critical materials, certain requirements must be met before consideration will be given to those seeking to enter the field. To pass upon such qualifications and to make the decisions necessary to permit allocations of materials to construct or convert a plant to dehydration, the War Production Board has set up a Dehydration Committee. In a general way, the order of consideration by the committee will be as follows:

1. First attention will probably be given to owners of machinery and equipment suitable for preparation of materials for dehydration. Since manufacture of this type of equipment requires the greatest amount of critical material of any used in the dehydration procedure, it is logical that those already possessing such equipment will receive primary consideration.
2. Next in line for favorable consideration probably will be those operating, or having available, large dehydrators capable of conversion.
3. Last to be considered will be those who have no equipment at present, but who are in sound financial condition and who can show they can obtain some of the necessary equipment that is not now in use.

If the operator feels that he can satisfy the committee's requirements, his next step is to present, in full detail, all of the facts concerning his proposed operation and to request the necessary forms. Application forms, entitled "Inquiry Regarding Conversion or Expansion of Existing Food Processing Facilities for Vegetable Dehydration," are obtainable from the Regional Office of the Food Distribution Administration, U. S. Department of Agriculture, San Francisco, California. If the application is approved, priorities will be granted and assistance given to further the development.

The foregoing restrictions apply only to prospective operators who wish to obtain military or lend-lease contracts. If it is desired to produce only for civilian use, the operator in possession of adequate equipment is free to go ahead without priorities.

# METHODS OF DEHYDRATION

## Single-stage method

Vegetables or fruit can be dehydrated satisfactorily by either a one- or two-stage process. The one-stage process is adaptable to the dehydrators now available in the state. The principle is simple especially where a counter-current flow is used. With the counter-current system the fruit or vegetable enters the drying tunnel at the cold end where the temperature is approximately 130° F. (Figure 1). The product moves against the air current toward the finishing or hot end of the tunnel. The incoming air at the hot end should not exceed 150° to 160° F. at any time. Most products, when they are reduced to a moisture content of approximately 5 to 7 per cent are susceptible to color change because of increased heat absorption by the product as the rate of evaporation decreases. With most fruit the finishing condition is different from that of vegetables. Fruit usually can contain 15 to 18 per cent moisture and still keep satisfactorily under normal storage conditions. This would mean then that the wet-bulb reading could be as high as 100° F.

With vegetables requiring a low moisture content, the moisture condition of the air should be much lower. It is therefore necessary when using 150° F. dry bulb to have a 90° to 95° F. wet bulb for the best results.

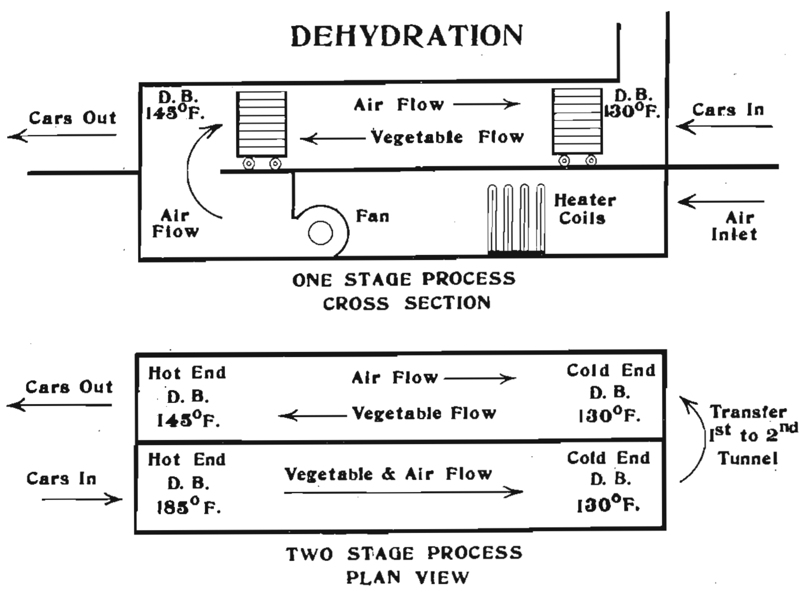


Figure 1. Single-stage and two-stage dehydration.

By proper control of conditions it is quite possible to run either fruit or vegetables through a single tunnel counter-currentwise and produce a finished product of acceptable quality and with the proper moisture content.

### Two-stage method

With the two-stage system the drying rate can be materially increased because it is possible to use higher temperatures at the beginning of the drying period. To illustrate this (Figure 1), the car of prepared vegetables is placed in the first tunnel at an initial temperature of 190° to 200° F. dry bulb, 90° to 95° F. wet bulb, and an air speed of at least 800 to 1,200 lineal feet per minute parallel to the flow of the material. The vegetable is subjected to this high temperature air while its moisture content is high. With this increased temperature rapid evaporation takes place and the vegetable is soon reduced in moisture content so that it comes into the critical phase of drying. At that point the car has traveled to the other end of the drying tunnel where the temperature may have reached 130° to 145° F. At this point the car is transferred to the second tunnel where the second or finishing stage of drying is carried on. In this final stage the temperature should not exceed 145° to 150° F. dry bulb so that the product will not be subjected to conditions that might cause color or flavor changes due to overheating. In this second tunnel the product runs in a counter-current fashion, the vegetable traveling against the air current as in the one-stage process (Figure 1).

Since quality factors in dehydrated food products are dependent, to an appreciable degree, on the length of time the vegetable has been subjected to drying temperatures, it is evident that the process providing for the most rapid removal of moisture, without raising the temperature above the critical point, will be the most acceptable. The two-stage process provides the higher temperatures necessary for rapid, early moisture removal without subjecting the nearly dry material at the finishing end of the dehydrator to excessive temperatures that will impair the final quality of the product.

### Relative humidity

At any given temperature a definite volume of air is capable of holding a definite amount of water as water vapor. If this air is actually holding the maximum amount of water, as vapor, it is capable of holding, it is spoken of as saturated and its RELATIVE HUMIDITY is 100 per cent. If the given volume of air is holding a lesser quantity of water than is required for saturation, it has a

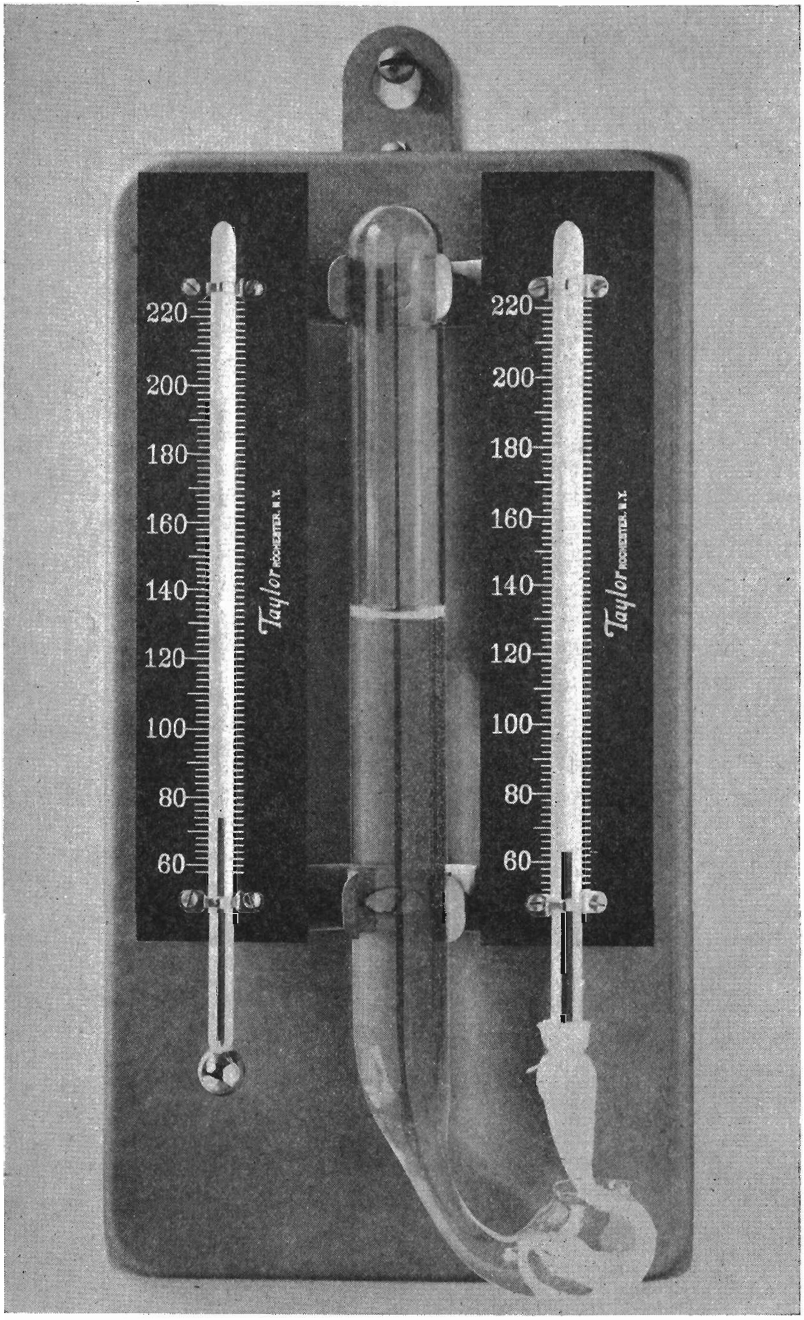


Figure 2. Wet Bulb and Dry Bulb thermometer.

relative humidity of *less* than 100 per cent. At any stated temperature:

$$\frac{\text{Amount of water vapor actually contained by the air}}{\text{Amount of water vapor the air is capable of containing}} \times 100 = \left\{\begin{array}{l}\text{Relative} \\ \text{humidity in} \\ \text{per cent}\end{array}\right.$$

Therefore, if air is holding only one-half of the amount of water vapor of which it is capable, its relative humidity is 50 per cent.

### Wet-bulb and dry-bulb temperatures

When evaporation takes place, heat must be supplied to the water in order that vapor may be formed. The result is a lowering of the temperature of the object from which evaporation is occurring. If the temperature and movement of the surrounding air are held constant, the rate of evaporation is governed by the degree of saturation of the atmosphere with moisture vapor. In other words, the rate of evaporation and the temperature of the object from which evaporation is taking place are dependent on RELATIVE HUMIDITY. This fact is utilized in a device known as a wet-bulb thermometer that indicates the temperature at the evaporating surface. This is accomplished by attaching a wick to the bulb and immersing the wick in a vessel of water. When the thermometer is placed in a rapidly moving current of air and water is freely evaporating from the wick at a rate governed by the humidity and temperature conditions of the atmosphere, the resultant temperature indicated by the thermometer is known as the wet-bulb temperature.

Wet-bulb temperature is of value only if used in conjunction with the ordinary dry-bulb air temperature to determine relative humidity. Regardless of what the two temperatures may be, the difference between the two readings is used to determine the relative humidity conditions. Table 2 indicates the relationships that exist at various wet-bulb, dry-bulb differences. As an example, if the dry-bulb (ordinary) air temperature is 145° F. and the wet-bulb temperature is 90° F., the relative humidity is 12 per cent.

## EQUILIBRIUM MOISTURE CONTENT

A wet material will give up moisture to dry surrounding air. A dry product will take moisture from moist surrounding air. The amount of water taken up by the dry material or given off by the wet product depends on the relative humidity and the temperature of the air in each case. When the product no longer gives up or takes on moisture, it is said to be in equilibrium with the air about it and the amount of water that the product contains under these conditions is called the "equilibrium moisture content."

Table 2. Relative Humidities Obtained from Differences Between Wet-Bulb and Dry-Bulb Temperature Readings

| Dry bulb reading | Difference between readings of wet and dry bulbs in degrees F. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Dry bulb reading |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | |
| *Degrees F.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | *Degrees F.* |
| 100 .... | 96 | 93 | 89 | 86 | 83 | 80 | 77 | 73 | 70 | 68 | 65 | 62 | 59 | 56 | 54 | 51 | 49 | 46 | 44 | 41 | 37 | 33 | 28 | 24 | 21 | 17 | 13 | 10 | 7 | 4 | 0 | | | | | | ....100 |
| 105 .... | 97 | 93 | 90 | 87 | 83 | 80 | 77 | 74 | 72 | 69 | 66 | 63 | 60 | 58 | 55 | 53 | 50 | 48 | 46 | 44 | 40 | 36 | 32 | 28 | 23 | 20 | 16 | 13 | 11 | 8 | 0 | | | | | | ....105 |
| 110 .... | 97 | 93 | 90 | 87 | 84 | 81 | 78 | 75 | 73 | 70 | 67 | 65 | 62 | 60 | 57 | 55 | 52 | 50 | 48 | 46 | 42 | 38 | 34 | 30 | 26 | 23 | 20 | 17 | 14 | 11 | 4 | 0 | | | | | ....110 |
| 115 .... | 97 | 94 | 91 | 88 | 85 | 82 | 79 | 76 | 74 | 71 | 68 | 66 | 63 | 61 | 58 | 57 | 54 | 52 | 50 | 48 | 43 | 40 | 36 | 32 | 28 | 26 | 22 | 20 | 16 | 14 | 7 | 2 | 0 | | | | ....115 |
| 120 .... | 97 | 94 | 91 | 88 | 85 | 82 | 80 | 77 | 74 | 72 | 69 | 67 | 65 | 62 | 60 | 58 | 55 | 53 | 51 | 49 | 45 | 41 | 38 | 34 | 31 | 28 | 25 | 22 | 19 | 17 | 10 | 5 | 0 | | | | ....120 |
| 125 .... | 97 | 94 | 91 | 88 | 85 | 83 | 80 | 78 | 75 | 73 | 70 | 68 | 66 | 63 | 61 | 59 | 57 | 54 | 52 | 50 | 47 | 43 | 40 | 36 | 33 | 30 | 27 | 24 | 22 | 19 | 13 | 7 | 2 | 0 | | | ....125 |
| 130 .... | 97 | 94 | 91 | 89 | 86 | 83 | 81 | 78 | 76 | 73 | 71 | 69 | 67 | 64 | 62 | 60 | 58 | 56 | 54 | 52 | 48 | 45 | 41 | 38 | 35 | 32 | 29 | 26 | 24 | 21 | 15 | 10 | 6 | 1 | 0 | | ....130 |
| 135 .... | 97 | 94 | 92 | 89 | 86 | 84 | 81 | 79 | 76 | 74 | 72 | 69 | 67 | 65 | 63 | 61 | 59 | 57 | 55 | 53 | 50 | 46 | 43 | 40 | 36 | 34 | 30 | 28 | 26 | 23 | 18 | 12 | 8 | 3 | 0 | | ....135 |
| 140 .... | 97 | 95 | 92 | 89 | 87 | 84 | 82 | 79 | 77 | 75 | 73 | 70 | 68 | 66 | 64 | 62 | 60 | 58 | 56 | 54 | 51 | 47 | 44 | 41 | 38 | 35 | 32 | 30 | 27 | 25 | 19 | 14 | 10 | 5 | 2 | | ....140 |
| 145 .... | 98 | 95 | 93 | 90 | 87 | 84 | 82 | 80 | 78 | 75 | 73 | 71 | 69 | 67 | 65 | 63 | 61 | 59 | 57 | 55 | 52 | 48 | 45 | 42 | 39 | 36 | 34 | 31 | 29 | 27 | 21 | 16 | 12 | 7 | 4 | 0 | ....145 |
| 150 .... | 98 | 95 | 93 | 90 | 87 | 85 | 82 | 80 | 78 | 76 | 73 | 71 | 70 | 68 | 65 | 64 | 62 | 60 | 58 | 56 | 53 | 49 | 46 | 43 | 41 | 38 | 35 | 33 | 30 | 28 | 23 | 18 | 13 | 9 | 5 | 2 | ....150 |
| 155 .... | 98 | 95 | 93 | 90 | 87 | 85 | 83 | 81 | 79 | 76 | 74 | 72 | 70 | 68 | 66 | 64 | 63 | 61 | 59 | 57 | 54 | 50 | 47 | 44 | 42 | 39 | 37 | 34 | 32 | 30 | 24 | 19 | 15 | 11 | 7 | 4 | ....155 |
| 160 .... | 98 | 95 | 93 | 90 | 88 | 85 | 83 | 81 | 79 | 77 | 75 | 73 | 71 | 69 | 67 | 65 | 63 | 62 | 60 | 58 | 55 | 51 | 48 | 46 | 43 | 40 | 38 | 35 | 33 | 31 | 25 | 21 | 16 | 12 | 9 | 6 | ....160 |
| 165 .... | 98 | 95 | 93 | 91 | 88 | 86 | 84 | 82 | 80 | 78 | 75 | 73 | 72 | 70 | 68 | 66 | 64 | 62 | 61 | 59 | 56 | 52 | 49 | 47 | 44 | 41 | 39 | 37 | 34 | 32 | 27 | 22 | 18 | 14 | 10 | 7 | ....165 |
| 170 .... | 98 | 96 | 94 | 91 | 89 | 86 | 84 | 82 | 80 | 78 | 76 | 74 | 72 | 70 | 69 | 67 | 65 | 63 | 62 | 60 | 57 | 53 | 50 | 48 | 45 | 42 | 40 | 38 | 35 | 33 | 28 | 23 | 19 | 15 | 12 | 9 | ....170 |
| 175 .... | 98 | 96 | 94 | 91 | 89 | 86 | 84 | 82 | 81 | 79 | 76 | 74 | 73 | 71 | 69 | 67 | 66 | 64 | 62 | 61 | 58 | 54 | 51 | 49 | 46 | 43 | 41 | 39 | 36 | 34 | 29 | 25 | 20 | 17 | 13 | 10 | ....175 |
| 180 .... | 98 | 96 | 94 | 92 | 89 | 87 | 85 | 83 | 81 | 79 | 77 | 75 | 73 | 72 | 70 | 68 | 66 | 64 | 63 | 61 | 58 | 55 | 52 | 50 | 47 | 44 | 42 | 40 | 37 | 35 | 30 | 26 | 21 | 18 | 14 | 12 | ....180 |
| 185 .... | 98 | 96 | 94 | 92 | 89 | 87 | 85 | 83 | 81 | 80 | 77 | 76 | 74 | 72 | 70 | 69 | 67 | 65 | 64 | 62 | 59 | 56 | 53 | 50 | 48 | 45 | 43 | 41 | 38 | 36 | 31 | 27 | 22 | 19 | 16 | 13 | ....185 |
| 190 .... | 98 | 96 | 94 | 92 | 90 | 87 | 85 | 83 | 82 | 80 | 78 | 76 | 74 | 73 | 71 | 69 | 68 | 66 | 64 | 63 | 60 | 57 | 54 | 51 | 49 | 46 | 44 | 42 | 39 | 37 | 32 | 28 | 24 | 20 | 17 | 14 | ....190 |

Courtesy The Foxboro Company

It will be found in practical plant operation that a lower relative humidity will be required to bring the product to a moisture content of less than 5 per cent than is indicated by reference to the equilibrium moisture chart (Figure 3). This is true, first, because some products give up water less readily than others, and, second, because the greater difference between wet- and dry-bulb temperatures will cause drying to be speeded.

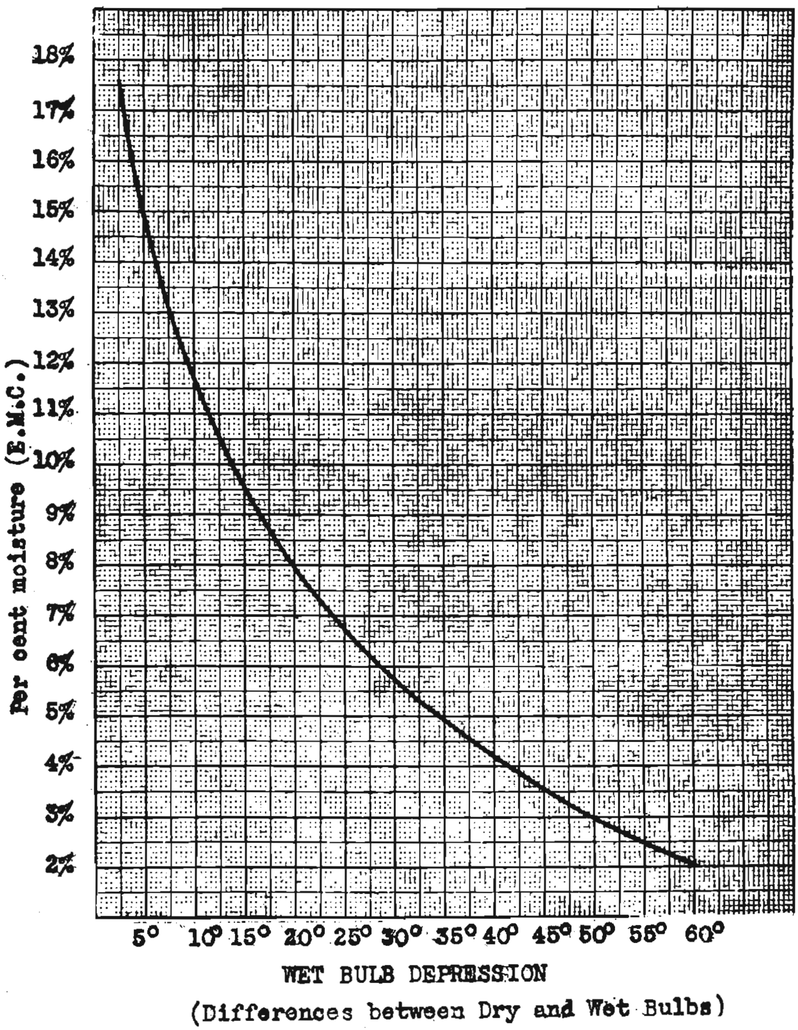


Figure 3. Equilibrium moisture chart.

It is suggested that the relative humidity actually used always be adequate to bring the product to an equilibrium moisture content of 2 to 3 per cent less than is indicated by the chart.

Since nearly all vegetables must be dried to a moisture of 5 per cent, or less, the operating conditions in the dehydrator should be such that the difference between dry-bulb and wet-bulb thermometer readings will be at least 50° to insure economical operation.

As was explained in the previous section, the relative humidity is determined by means of a wet-bulb and dry-bulb thermometer. Figure 3 is so drawn that the average equilibrium moisture content is easily read when the difference between dry and wet bulbs is known. It must be realized that the equilibrium moisture contents as indicated on the chart are values that constitute an average for different vegetable materials. Actually the true value will differ between different products and also vary for each material with differences in variety, maturity, type of pretreatment, etc. By use of the equilibrium moisture content for a particular vegetable at a given temperature, it is possible to determine what relative humidity is necessary in order to obtain a dried product of the required final moisture content.

## GENERAL HANDLING AND PRETREATMENT

High-quality raw materials are essential. It is true that if high-quality fresh fruits and vegetables are poorly stored, handled, and prepared a low-quality dehydrated product will result. Nevertheless, the best handling and preparation technique that experience and experiment can provide can never make a good dehydrated product from a poor raw one.

In any food-drying operation, the preliminary preparation and pretreatment given the raw material is the first essential processing step. Unless sufficient consideration and care are given to this phase, the resulting product will be of inferior quality and will ultimately reflect on future business. As it is the desire of most manufacturers who are now dehydrating vegetables to develop later a domestic trade for their products, close attention will have to be given to the details that have a bearing on palatability and nutritive characteristics. As in freezing fruits and vegetables, preliminary handling is as important as the final manufacturing procedure. Many of the lessons learned in freezing have been applied successfully to dehydration.

## DEHYDRATING FRUIT

Fruits, in general, require little pretreatment other than sulphuring to preserve color and prevent deterioration in storage. A minimum of handling is desirable. In each case, sorting must be done to remove fruits unfit for dehydration. The following treatments, using the conventional single-stage dehydrating system for the individual fruits, have been found to be successful in practice. For each fruit the two-stage method can be applied with equally satisfactory results while offering the advantage of increased production.

When dehydrated fruits are to be sold to the Federal Government, applicable specifications must be met. The specifications can be obtained from the Quartermaster Corps Subsistence Laboratory, U. S. Army, Chicago, Illinois.

### Apples

1. Apples require peeling, coring, and trimming with loss of 35 to 40 per cent of initial weight.
2. Place fruit in tank of 1½ to 2 per cent salt brine (6° to 8° salinometer).
3. Slice into rings ¼-inch thick or cut into quarters.
4. Tray on wood trays immediately after slicing with load of 1½ pounds per square foot.
5. Stack on cars and sulphur for 1½ hours to 2 hours (see Appendix).
6. Dehydrate with entering temperature of 130° F. and finishing temperature of 155° F. with wet bulb at 100° F.
7. Dry 8 to 10 hours using recirculation.
8. Final moisture content approximates 15 per cent with maximum of 22 per cent for shipping.
9. For overseas use, moistures of about 10 per cent or lower are necessary. Resulphuring after dehydration is required to insure proper keeping qualities under adverse storage conditions.
10. One pound dried fruit is obtained from about 7 pounds unprepared fruit.

### Apricots

1. Split fruit in half and remove pit.
2. Place on wood slat trays and sulphur for 2 to 3 hours, keeping pit cavity up.
3. Dehydrate with entering temperature of 135° F. and finishing temperature 155° F., wet bulb 100° F.

4. Drying time will vary from 10 to 18 hours depending on equipment used.
5. Final moisture 12 per cent.
6. Drying ratio 6 to 7 pounds fresh to 1 pound of dry.
7. Lower moisture content and resulphuring should apply for overseas use.

**Berries**

1. Light spray washing is advisable for berries growing near ground. Avoid excessive handling.
2. Sulphuring of 30 minutes to 2 hours may be desirable for strawberries.
3. Spread on trays 1½ to 2 pounds per square foot.
4. Dehydrate with entering temperature of 130° F. and finishing temperature of 150° F. Wet bulb 100° F.
5. Drying time 6 to 12 hours.
6. Final moisture content should not exceed 15 per cent and considerably lower for overseas use.
7. Yield 1 pound dry product from 3 to 5 pounds fresh fruit.
8. Steam treat before boxing (see section on packaging).

**Cherries**

1. Dry with or without stemming and pitting.
2. Sulphuring advantageous 30 minutes to 1 hour; 3 to 5 minutes blanch before sulphuring is optional.
3. Tray loads should not exceed 2 to 2½ pounds per square foot with one layer of fruit.
4. Dehydrate with entering temperature of 130° F. and finishing temperature of 155° F. Wet bulb 100° F.
5. Final moisture content 16 to 18 per cent. For overseas shipment lower moistures are necessary.
6. Steam fruit to sterilize before packing (see section on packaging).
7. Drying ratio 3 to 4 pounds of fresh fruit will produce 1 pound of dried.

**Cranberries**

1. Wash fruit in running cold water.
2. Spread on trays with load of .8 to 1 pound per square foot. Chopping before traying is optional. Light sulphuring materially improves the color.
3. Dehydrate at 135° F. entering temperature with 150° F. finishing temperature. Wet bulb 90° to 95° F.

4. Drying time 5 to 8 hours.
5. Final moisture content 5 per cent.
6. Yield 1 pound of dehydrated berries for each 7 pounds fresh fruit.

**Peaches**

1. Cut fruit in half and remove pit.
2. Blanching is optional before sulphuring.
3. Sulphur for 3 to 4 hours or longer depending on size of fruit and desired final use.
4. Dehydrate with entering temperature of 130° F. and finishing temperature of 155° F. Wet bulb 100° F.
5. Drying time varies from 18 to 22 hours, depending on size of fruit and type of dehydrater.
6. Final moisture 15 to 18 per cent for domestic use. For overseas shipment final moisture should not exceed 12 per cent.
7. Drying ratio will be 4 or 5 to 1 for products dried for domestic use.

**Pears**

1. Assure full ripeness of fruit by storage at 65° F. to 68° F. at 80 per cent relative humidity for necessary length of time.
2. Cut fruit in half and spread on trays.
3. Sulphur for 2 to 12 hours.
    a. Short sulphuring produces a light, opaque product with characteristic flavor.
    b. Long sulphuring produces the more common translucent product.
4. Dehydrate with entering temperature of 135° F. and finishing temperature of 155° F. Wet bulb temperature 100° F.
5. For domestic use, final moisture should be 16 to 18 per cent; for overseas shipment, 10 per cent or less.
6. Drying ratio approximates 4 or 5 to 1 when product is dried for domestic consumption.

**Prunes (Italian, Petite, and Date)**

1. Special attention should be given to washing and sorting to eliminate all decayed or damaged fruit.
2. Steam blanching is optional. The blanched product resembles the fresh fruit more closely on cooking than does the unblanched dried prune.
3. Remove pits to speed drying rate, thereby improving quality. This operation is optional.

4. Spread on trays with load of approximately 3 pounds per square foot.
5. Dehydrate with entering temperature of 140° F. and final temperature of 165° F. Wet-bulb temperature 110° F.
6. Final moisture content is 18 to 20 per cent. For overseas use moisture must not exceed 14 per cent.
7. Drying ratio is 3 to 1 for Italian prunes and 2½ to 1 for the Petite variety.

## VEGETABLE BLANCHING*

A high percentage of the dried vegetables produced during the first World War were tough and either tasteless or decidedly off in flavor and odor. Most of their dietary value had been lost in processing and it is small wonder they receive an unenthusiastic reception by the men to whom they were served. It is known now that most of the undesirable characteristics of these earlier products were due to the action of enzymes that had not been inactivated prior to dehydration. All of the enzyme systems involved in the complicated reactions that lead to the undesirable changes found during storage are still not known. Since heat destroys enzymes, one of the most heat-stable enzyme systems—peroxidase—has been selected as the test enzyme. It is assumed that, if peroxidase is destroyed, it is highly probable that other enzymes involved in reactions leading to quality deterioration will likewise have been inactivated.

Since heat destroys enzymes, the required practice for modern dehydration is the blanching or scalding of vegetables at such temperatures of hot water or steam for such periods as are necessary to produce a material that will react negatively to a qualitative test (see Appendix) for peroxidase.

It may be mentioned that the blanching conditions required to produce a negative peroxidase test, as it is now interpreted, may be in excess of those required to produce quality stability in storage for some vegetables. In the case of rutabagas, for example, it has been demonstrated that, in more than 30 minutes of blanching, the peroxidase system apparently may not be destroyed. In cases of overblanching there is a serious loss of nutritional values.

Three methods of blanching are in more or less common use: steam blanching, water blanching, and series blanching. In steam blanching the material is subjected to live steam, in suitable equipment, at temperatures of 212° F. or above. In water blanching, the

* The authors acknowledge assistance on blanching technique given by Dr. Horace Campbell of Western Regional Research Laboratory, U. S. Department of Agriculture.

product is passed through or held in boiling water. Series blanching is a type of water blanching in which the soluble solids leached from the vegetables during blanching are allowed to accumulate in the blanch water until a concentration of about 4 per cent is achieved. This concentration is then maintained by the gradual introduction of fresh water and removal of spent water.

Each blanching method has certain advantages and disadvantages. In steam blanching the advantage is the reduction in removal of soluble solids and vitamins as compared with water blanching. The disadvantage of steam blanching lies in the difficulty in obtaining a uniformly blanched product. The advantages of water blanching are uniformity and reduction of blanching time. The disadvantage is the generally accepted fact that water blanching results in a greater loss of soluble materials than does steam blanching. Series blanching, recommended by British investigators, is considered to cause less loss of soluble materials than water blanching but not necessarily less than that caused by steam blanching. At present, steam blanching is generally recommended and the specifications of the U. S. Army Quartermasters Corps require that the product be steam blanched before dehydration.

As many factors influence the length of time required for an adequate blanch for different materials, definite recommendations are unfortunately difficult to make. Among those factors are:

1. Size of produce pieces. A temperature of at least 190° F. must be reached in the center of each piece. It is obvious that the larger the piece the longer it takes to reach the proper center temperature.
2. Amount of material loaded into blancher. Again time required for heat penetration is the controlling factor.
3. Depth of material loaded on blanching trays or belt.
4. Uniformity of heat distribution in the blancher.
5. Ability of blancher to maintain a constant temperature.
6. Characteristics of the raw material, such as variety and maturity.
7. Altitude at which blancher is operated. The higher the altitude, the lower the temperature will be, under atmospheric pressure, for live steam or boiling water treatments.

In order to eliminate variations in the blanching operations as much as possible, observation of the following precautions by the operator will be of value:

1. The blancher must be of proper design. The maintenance of temperature, uniformity of heat distribution, and an adequate supply of steam are essential. Thermometers should be pro-

vided at various points so that heat conditions can be checked frequently and easily.

2. Provisions must be made for uniform loading and spreading of material.
3. Provision should be made to take samples of the blanched material to be checked for enzyme activity at frequent intervals during the course of operation.

If the general precautions enumerated above are followed, coupled with common sense and judgment and observance of the more specific instructions for the various crops detailed below, the dehydrator should produce a material of stable and satisfactory quality. In all cases delay between blanching and dehydration should be avoided. Under no circumstances should blanched material be held longer than 1 hour between these operations.

## PROCEDURE FOR VARIOUS CROPS

### IRISH POTATOES (OREGON GEMS, KLAMATH RUSSETS, AND BURBANKS)

#### Handling

Storage conditions should be maintained at a cool, even temperature. Bags should be stacked, in an insulated room, to provide proper conditions. On removal from cool storage, potatoes should be placed in storage at 65° to 70° F. to improve quality of finished product.

#### Preparation

Thorough washing is usually done in a corrugated drum or squirrel-cage washer equipped with sprays. Grading to size should be performed to speed peeling and reduce waste. A light preblanch for a few minutes will tend to soften the outer skin, which facilitates the peeling operation. Peeling is done by use of continuous or discontinuous abrasive peelers or by passing through a boiling lye bath (5 per cent caustic) followed by strong sprays of cold water or a special machine to remove the loosened peels. A new patented technique has been developed by L. Charles Mazzola of Auburn, N. Y., by which solutions of more than 20 per cent by weight of lye at the boiling temperature are employed for, it is claimed, very rapid penetration and loosening of the skin without the excessive waste occasioned by more dilute solutions and by the abrasive type of peelers. In order to use the high lye concentration technique, arrangements must be made with Mr. Mazzola. The use of saturated, salt-brine peeling bath is a new method now being developed.

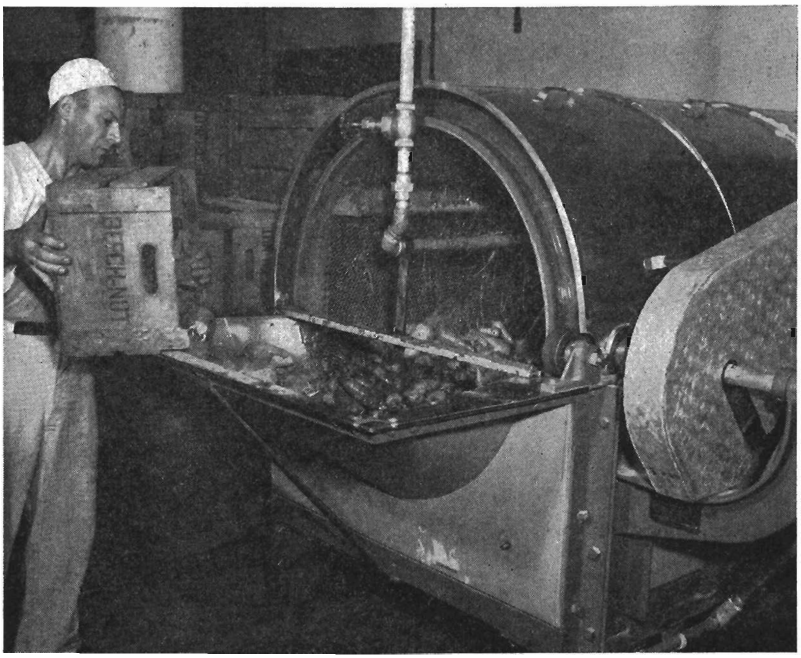


Figure 4. Rotary washer for root crops in plant of Beechnut Packing Company, Rochester, New York.

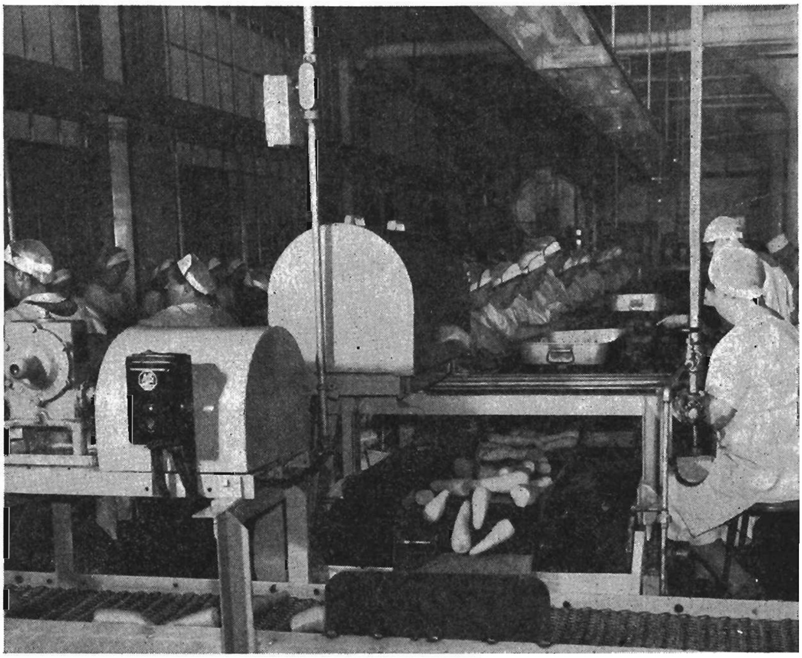

Figure 5. Trimming tables in dehydration plant of Beechnut Packing Company, Rochester, New York.

Following peeling, eyes and black spots are removed by trimming. Total waste approximates 15 to 17 per cent when most efficient methods are used. It may possibly be lower if the strong lye technique is followed, or higher when abrasive methods are used.

Potatoes may then be prepared for dehydration in one of four ways: slicing, dicing, shredding, and ricing. The first three forms can be produced by the same equipment by making the necessary change of parts when changing from one of the forms to another. The cut material must be held under potable cold water or clean 2 per cent salt solution if it does not pass directly into the blancher after cutting. This will prevent discoloration from enzymatic oxidation, but the material should not be held thus for more than 1 hour. Immediately prior to blanching, the cut material should be sprayed with clean cold water to remove loose starch on the cut surfaces.

**Blanching**

It is recommended that blanching be carried out in a blancher in which the temperature is that of boiling water or that of live steam at atmospheric pressure. In order to meet the Federal Surplus Commodities Corporation Specifications of September 1942, and the U. S.

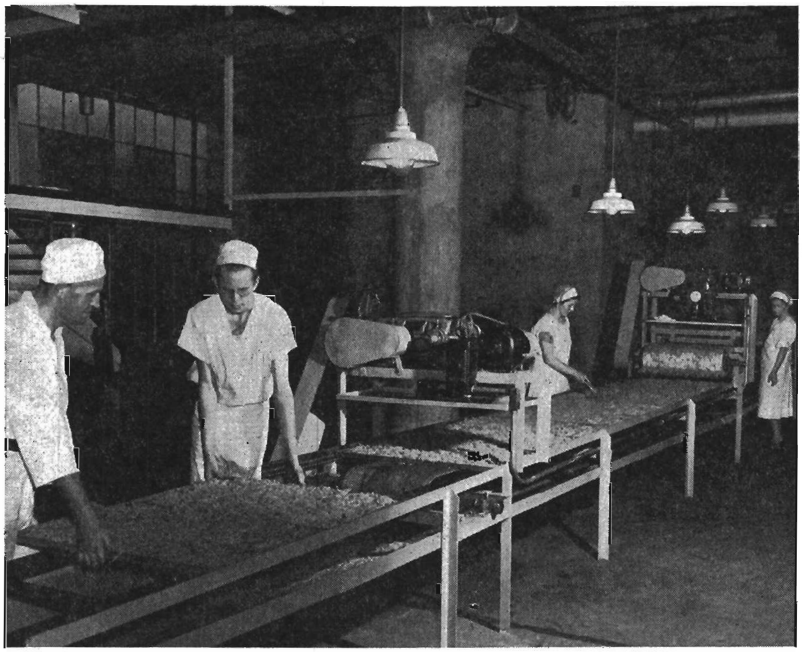

Figure 6. Traying and handling blanched carrots in plant of Beechnut Packing Company, New York.

Army Specifications of April 16, 1942, for blanching, the material must be blanched until the peroxidase system is inactivated. (See Appendix.) The time required for this will probably vary from 4 to 10 minutes, depending on the factors previously mentioned as affecting blanching time. The suggested blancher loading is approximately 1½ pounds per square foot of surface.

After blanching, the material should be sprayed again with clean water to remove loose starch that might otherwise cause the pieces to stick together during dehydration.

Riced potatoes must be precooked after slicing to soften the product. Usually 15 to 25 minutes is necessary to soften the potatoes. While still hot, they are passed through a machine similar to a sausage grinder with a specially designed head that gives the ricing effect. These riced shreds do not need further treatment and are placed on the tray for dehydrating at a load of 1 to 1¼ pounds per square foot.

### Dehydration

Drying time is variable with different types of products, but is usually 2 to 4 hours. Recommended entering temperature is 135° F. and finishing temperature should not exceed 150° F. with wet-bulb temperature of 90° to 95° F. Final moisture content should not be greater than 7 per cent for sliced, diced, or shredded nor greater than 8 per cent for riced material. Where a two-stage drying system is adopted, the initial temperature can range from 190° to 200° F. dry bulb with a wet bulb of 95° to 100° F. in the first unit. In the second unit the maximum temperature should not exceed 145° F. dry bulb with 90° to 95° F. wet bulb. The drying ratio varies between 7 and 9 to 1.

## CARROTS (CHANTENAY, MORSE BUNCHING AND IMPERATOR)

### Handling

Washing carrots on arrival at the plant in bulk, sacks, or field boxes is important. Usually these roots are covered with mud which, if allowed to remain, would increase loss due to mold and decay during storage.

### Treatment

Grading to size is necessary to reduce peeling waste. After grading, the carrots can be peeled by an abrasive or flame peeler. The flame peeler will be slightly more economical of raw material and will facilitate handling. This peeling method may be more costly, however, because of type of fuel used in its operation. Either lye or a combination of lye and abrasive peeling has been found to give satisfactory results.

Trimming is required to remove green ends and spots along the sides of the carrot that have not been removed in the peeling operation. The total preparation waste between the two systems approximates 19 per cent for flame peeling against 24 per cent for abrasive peeling.

Carrots are cut into strips not less than 3/4 inch long by not less than 3/16 inch or more than 6/16 inch, diced 3/16 inch to 6/16 inch, or sliced 3/16 inch to 4/16 inch. These operations can be carried on by the same machine by making the necessary changes of parts as shifts from one form to another are required. As this process sometimes causes chips to form, it is good practice to give an additional wash at this point.

### Blanching

Sliced, cubed, and stripped carrots should be blanched as soon as possible after preparation. If the material cannot pass directly from the cutters to the blancher, it should be held in clean cold water or clean 2 per cent salt solution. In any event, the material should not be so held for more than 1 hour. Just prior to blanching the cut carrots should be washed with sprays of clean water.

It is recommended that blanching be carried out in live steam. The blanching time should be adjusted so that complete destruction of the peroxidase system will be assured and the Federal and U. S. Army Specifications for this product will be met. The time required may vary from 4 to 10 minutes, depending on the various factors affecting blanching time, which have been indicated in the general discussion on blanching. (Also see Appendix.) A suggested blancher loading is 1½ to 2 pounds per square foot of loading surface.

There should be as little delay as possible between blanching and dehydration, and in any event the delay period should not exceed 1 hour.

### Dehydration

The product, after blanching, is spread on trays with a load of 1¼ to 1½ pounds per square foot. Entering temperature is usually 135° F. and finishing temperature not more than 150° F., usually 145° F. with wet-bulb temperature of 90° to 95° F. Final moisture content of the product should not exceed 5 per cent. Application of the two-stage system explained under "Potatoes" can be made with this vegetable satisfactorily. The drying ratio varies between 8 and 11 to 1.

## BEETS (DETROIT RED)

### Handling

Beets should first be washed in a rotary washer to remove the mud and foreign material. Storage can be in bins, if in bulk, or on the receiving platform if the product is received in containers. Beets should be used as quickly as possible to prevent darkening that takes place in storage.

Grading before peeling effects a considerable saving. Field-run beet losses up to 30 per cent are often encountered while with size grading this is reduced to 13 to 29 per cent for the various grades.

Peeling and cutting are usually performed following the blanch. These operations may be performed before blanching, but there may result an excessive loss of color if this order is followed.

### Blanching

Specifications of the U. S. Army and of the Federal Surplus Commodities Corporation, both dated September 1942, require that beets be blanched whole in live steam for 25 minutes or more, or until the peroxidase system is inactivated. Care should be taken not to overcook, as this will result in excessive waste during peeling.

### Treatment

Peeling can be done with abrasive or flame peelers. Both methods have been found successful. In most cases an abrasive continuous or discontinuous operation will be used because of the difficulty in obtaining flame peelers and the cost of their installation. After peeling, thorough trimming is necessary to remove black spots or decay.

After trimming, the beets are either sliced, cubed, or stripped. Slices are 3/16 to 1/4 inch in thickness, while the cubes vary from 3/16 to 3/8 inch to a side. Strips are cut into sizes not less than 3/4 inch in length with cross sections not less than 3/16 or more than 3/8 inch. These sizes are all obtainable from the same machine with minor changes.

Where precooking is practiced, no further blanching is necessary.

### Dehydration

The tray load for dehydration should be from 1 to 1½ pounds per square foot. Entering temperature should be 135° F. and the finishing temperature should not exceed 150° F. in the counter-current dehydrater. The wet bulb should be maintained at 90° to 95° F. The final moisture must not be greater than 5 per cent in the dehydrated product, with drying ratio varying between 8 and 9 to 1. The two-stage process can be applied to this product.

## RUTABAGAS (AMERICAN PURPLE TOP, BANGHOLM, EARLY NECKLESS)

### Handling

This crop may be handled in a manner similar to carrots. Care should be exercised in washing, storing, and later grading to size.

### Treatment

Since this crop is firmer in texture than are beets and the skin is much tougher, a preliminary blanch of 10 to 15 minutes, depending on size, is recommended before peeling in an abrasive peeler. After peeling, the rutabagas are carefully trimmed and cut into slices, cubes, or strips according to requirements.

### Blanching

After cutting, the rutabagas are sprayed with cold water and blanched immediately. Should there be any delay between these operations, immersion in potable cold water or clean 2 per cent salt solution would be necessary. Under no circumstances should the product be thus held for longer than 1 hour. According to the specifications of the U. S. Army of August 26, 1942, and of the Federal Surplus Commodities Corporation of September 1942, blanching should be conducted with live steam for such a period that the peroxidase system will be inactivated. This requirement presents a problem, however, since recent experience indicates that, in the case of rutabagas, the test for peroxidase as now interpreted may show positively after a blanch of 30 minutes or longer under ideal conditions. Practical operations indicate that this specification should be modified. It is believed that, regardless of the specification, a product that will keep well in storage will result from the use of a live steam blanch of from 5 to 10 minutes. Delay between blanching and dehydration should not exceed 1 hour. The suggested blancher loading is 1½ to 1¾ pounds per square foot.

### Dehydration

The tray load for dehydration should be 1¼ pounds per square foot. Entering temperature in a counter-current dehydrater should be 135° F. and finishing temperature should not exceed 150° F. dry bulb with a wet bulb of 90° to 95° F. Final moisture content of the dehydrated product should not exceed 5 per cent. The drying ratio varies between 8 and 10 to 1 from the fresh-prepared product to the dried vegetable. The two-stage process can be applied to this product.

## SWEET POTATOES (PUERTO RICAN, MARYLAND SWEETS, KEY WEST, JERSEY, AND NANCY HALE)

### Handling

Care as to storage temperatures and stacking of bags during storage should be observed. Size grading should be done before peeling.

### Preparation

Abrasive or lye peeling can be practiced, followed by such trimming as is necessary to remove objectionable portions. The sweet potatoes may then be cut into slices, cubes, or strips. If the material does not pass immediately into the blancher, it should be held in potable cold water or 2 per cent salt solution, but not for longer than 1 hour. If under these conditions the product persists in discoloring, a citric-acid solution of 1 or 2 per cent may be substituted for water or brine. Immediately before blanching the cut pieces should be washed with sprays of cold water.

### Blanching

Live steam is recommended for blanching. Blanching time must be regulated to accomplish complete inactivation of the peroxidase enzyme system in order that the specifications of the U. S. Army of April 17, 1942, and of the Federal Surplus Commodities Corporation of June 1942 be met. The time required may be from 6 to 10 minutes. (See Appendix.) In no case should there be a delay of more than 1 hour between blanching and dehydration. The suggested blancher loading is 1½ to 2 pounds per square foot.

If shredded, riced, or powdered sweet potatoes are required, the whole potatoes may be cooked thoroughly in live steam, followed by peeling and ricing. For the powdered product, moisture must not exceed 3 per cent. Powdering is done after drying.

### Dehydration

The recommended tray load for dehydration is 1¼ to 1½ pounds per square foot for sliced, diced, or stripped sweet potatoes and ¾ to 1 pound for the riced product. Entering temperature, counter-current system, is 140° F. and finishing temperature should not exceed

165° F. with wet bulb of 95° to 100° F. Final moisture content should not be greater than 7 per cent. The drying ratio varies between 3 and 4 to 1.

## ONIONS (EBENEZER, WHITE PORTUGAL, RED CREOLE, WHITE CREOLE, MOUNTAIN DANVERS)

### Handling

Onions are usually received at the dehydrator in bags that should be piled to prevent overheating until they are used.

### Preparation

The onions are washed and the top and root base are cut away. This operation loosens the paperlike outer layers, which can be removed in an abrasive peeler. Commonly, peeling is omitted and the outer skins are removed by suction after dehydration. Whether or not they are peeled, the onions are trimmed on conveyor belts and passed through slicing machines where they are cut into slices ¼ inch thick. Material lost in preparation is nominal, usually ranging from 11 to 13 per cent.

### Blanching

The specifications of the Federal Surplus Commodities Corporation and of the U. S. Army do not require that onions be blanched. Some operators, however, practice blanching because of their belief that storage life of the product is prolonged if blanching is done. There is evidence that the blanched product is more tender and of superior texture than unblanched material when rehydrated and cooked. Blanching, however, makes a product less attractive in appearance and there may be a marked loss of flavor and pungency, especially if the blanching time in live steam is longer than 1 to 1½ minutes.

### Dehydration

The tray load for dehydration should not exceed 1¼ pounds per square foot. Entering temperature with counter-current system should be 130° F. and finishing temperature should not exceed 140° F. with wet bulb 90° to 95° F. Final moisture should not be more than 4 per cent. The drying ratio varies from 9 to 11 to 1.

## CABBAGE (DANISH, DOMESTIC, AND PAINTED HEAD VARIETIES)

### Handling

As most of the Vitamin C is contained in the outer leaves of the cabbage, care should be taken to conserve these leaves by careful handling. Storage of this vegetable is usually done in large bins. Considerable hand labor is required, but a properly arranged conveyor system from the storage to the trimming tables will reduce hand work.

### Preparation

Trimming consists in removing the outer bruised and discolored leaves. Trimming waste ranges from 15 to 37 per cent. After trimming, the core is usually removed with especially designed rotary cutters.

Washing by strong sprays in a rotary-drum washer before shredding will clean out the dirt and grit. Shredding is done with a rotary cabbage cutter. The usual thickness is $\frac{1}{8}$ inch and not more than $\frac{1}{4}$ inch. Too fine a cut causes the vegetable to collapse during blanching.

### Blanching

The blanching operation should be performed immediately after shredding. If it is impossible to avoid delay at this point, the delay should never exceed 1 hour, and the material, meanwhile, should be held in potable cold water or clean 2 per cent salt solution. Just before blanching, the product is washed by cold-water sprays. To comply with the U. S. Army Specifications of July 16, 1942, and the Federal Surplus Commodities Specifications of September 1942, blanching must be conducted in live steam until the peroxidase system is destroyed. (See Appendix.) The time of blanching will be governed by the factors mentioned previously, but it may be 3 or 4 minutes, or more. It is imperative that overblanching be avoided to prevent undesirable color changes. The recommended blancher loading is 1 to $1\frac{1}{4}$ pounds per square foot. Recent work indicates that light sulphuring before blanching improves quality and appearance.

### Dehydration

The blanched product should go immediately to the dehydrator, but if delay is necessary, the material should be cooled by sprays of clean, cold water to 65° or 70° F. This precaution is essential to protection of color. The delay between blanching and dehydration should not exceed 1 hour. Tray loading for dehydration should not exceed 1 pound per square foot and traying should be done evenly to eliminate wet spots. Entering temperature with counter-current system should be 130° F. and finishing temperature should not exceed 150° F. with wet bulb at 90° to 95° F. Final moisture should not be greater than 4 per cent. The drying ratio varies between 18 and 20 to 1.

## SPINACH AND OTHER GREENS

### Handling

Holding these crops for any extended period should be avoided because of the tendency of greens to heat, wilt, and decay quickly. The loss of ascorbic acid is very rapid after harvesting.

### Preparation

The important problems in handling these crops are trimming, sorting, and washing. As a rule, considerable care in sorting is required after the roots have been cut away. All yellow, bruised, and insect-punctured leaves should be removed. After trimming the greens are placed in a large agitating washing tank to remove all mud and grit. Thorough agitation of the water is important to this operation.

### Blanching

The leaves of spinach and other greens should be blanched immediately after preparation. Holding between trimming and blanching should not exceed ½ hour. Blanching is conducted in live steam for a long enough time to inactivate the peroxidase system (See Appendix.) Usually 1 to 2 minutes will be required. Loading in the blancher should not exceed 0.8 pound per square foot and care should be taken that the load is spread evenly.

### Dehydration

As was mentioned for cabbage, there should be no delay between the blanching and dehydration operations. If delay cannot be avoided, the blanched product should be cooled at once to 65° to 70° F. by means of cold water—sprays or immersion. If this precaution is not observed, an undesirable brownish color is likely to be developed in the finished product. Under any circumstances, delay at this point should not exceed 1 hour. The greens are spread in a thin layer on trays for dehydration at a load of not more than ½ pound per square foot. Entering temperature with counter-current system should be about 135° F. and finishing temperature should not exceed 150° F. with wet bulb of 90° to 95° F. Final moisture should not be greater than 4 per cent. The drying ratio varies between 18 and 20 to 1.

## TOMATOES (FIRM-FLESHED ONLY)

### Handling

Tomatoes are usually received in lugs of approximately 35 to 50 pounds. The tomatoes should be mature for dehydration. Prolonged holding at the plant is not possible because of the rapidity at which decay takes place.

### Preparation

After thorough washing in a spray washer, the tomatoes are scalded in steam or boiling water for a few seconds to loosen the skin, chilled in cold water, and peeled by hand. In some cases suction tubes are used to remove this loose skin, which is quickly carried away. Slicing can be accomplished by running the peeled stock against rapidly revolving knives. A slice with thickness of not more than ¼ inch is recommended. It is also possible to slice the tomatoes in half and dry in that form.

### Blanching

The sliced tomatoes are blanched in live steam for 2 to 3 minutes with care exercised to prevent overblanching because of the danger of food loss due to the succulent nature of the material. A blancher loading of about 1 pound per square foot should be used.

### Dehydration

There should be no delay between blanching and dehydration. Traying at a load of 1½ pounds per square foot for halved tomatoes or 1¼ pounds per square foot for sliced tomatoes should not be exceeded. Entering temperature with counter-current system should be about 135° F. and finishing temperature should not exceed 150° with wet bulb at 90° to 95° F. If pulverizing is to be done following dehydration, the final moisture content should be 3 to 4 per cent, or less. Eighteen to twenty pounds of prepared fresh product will yield 1 pound of dried tomatoes.

## SWEET CORN (GOLDEN CROSS BANTAM)

### Handling

Sweet corn should be harvested at the milk stage for best results in drying. It is conveyed to the dehydrating plant in bulk and handled at the plant by power-conveying equipment that conveys it to bins for temporary storage. Corn has a tendency to heat; therefore rapid handling is important.

### Preparation

Automatic husking machines should be employed to handle this product effectively. These machines will husk from 1½ to 2 tons of corn per hour. Trimming is done at this point to remove undesirable portions from the ear.

### Blanching

Clean water should be used to wash the trimmed ears just before blanching. Live steam is used for blanching for a period of 8 to 10 minutes, or until the peroxidase test applied to the water extract of the blanched material, after filtering off skin and cob tissue, is negative. (See Appendix.) Blanching on the ear sets the milk and prevents excessive loss of water-soluble nutritive materials.

### Cutting

Following blanching, the ears are immersed in clean, cold running water to reduce the temperature of the product to 65° to 70° F. Cutting from the cob is done by continuous corn cutters that are able to handle 2 tons per hour satisfactorily. No further washing to remove chaff and cob tissue should be done before dehydration. Yield of cut corn varies between 35 and 40 per cent of total weight used.

### Dehydration

As the corn comes from the cutter it is spread on trays with a load of 1.7 pounds per square foot. Entering temperature with counter-current system should be about 135° F. and finishing temperature should not exceed 165° F. at 95° to 100° F. wet bulb. Final moisture should not be greater than 5 to 6 per cent. The drying ratio varies between 3½ and 4 to 1.

Extraneous material such as chaff and cob tissue can be removed after dehydration by passing the product through a fanning mill.

## GREEN BEANS (BLUE LAKE, KENTUCKY WONDER, REFUGEE)

### Handling

Beans are usually picked undermature to obtain the best quality. Handling on the receiving platform of the plant is not difficult but storage conditions must be carefully controlled to prevent decay. Dumping on a well-aired platform will prevent heating and reduce vitamin loss.

### Preparation

Grading to size is an important waste-reduction operation. Following grading the beans are cut by automatic machines and are then washed thoroughly.

### Blanching

Following cutting and washing, blanching in live steam should be done as soon as possible. It is recommended that a blanching time of at least 10 minutes, or long enough to inactivate peroxidase and catalase, be used at a blancher loading not in excess of 2 pounds per square foot. (See Appendix.) Overblanching must be avoided to prevent color deterioration. Following blanching the product is cooled immediately to 65° to 70° F. by cold water sprays to set and protect the color.

### Dehydration

The tray load for dehydration should be about 0.8 pound per square foot. Entering temperature with counter-current system should be 135° F. and finishing temperature should not exceed 155° F. with wet bulb at 90° to 95° F. Final moisture should not be greater than 5 per cent. The drying ratio varies between 10 and 12 to 1. Application of the two-stage system is possible.

## GREEN PEAS (STRATAGEMS, ALDERMAN, THOMAS LAXTON, GRADUS)

### Handling

Peas should be handled quickly after they have been harvested. Need for dispatch in this matter must be very strongly emphasized. Long delay in handling reduces the food value and flavor through heating and excessive respiration. In some plants the entire process of vining and shelling is done in one operation. The most recent development is to handle the vining and separation in the field. The shelled peas are conveyed to the plant in field boxes. As soon as this product is removed from the shell, heating starts rapidly, and crushed ice should be mixed in with the peas in the field boxes. If a holding period is necessary between shelling and blanching, the product should be kept at 32° to 34° F. or the peas should be kept covered with crushed ice.

### Preparation

Before blanching, the peas are run through a washer and quality separator that removes the overripe peas.

### Blanching

Live steam is used for blanching. The time necessary is at least 2 to 4 minutes with a blancher loading of about 1 pound per square foot. (See Appendix.)

### Dehydration

If delay occurs between blanching and dehydration, cooling of the material by use of cold, clean water to 65° to 70° F. is advised. Tray load is recommended at about 1 pound per square foot. Entering temperature with counter-current system is 135° F. and finishing temperature should not exceed 150° F. with wet bulb 90° to 95° F. Final moisture should not be in excess of 5 per cent. The drying ratio varies between 4 and 5 to 1. The two-stage system of drying can be applied to this product.

## GREEN LIMA BEANS (HENDERSON'S BUSH AND BABY FORDHOOK)

### Handling

Need for speed in handling, as with peas, so that the limas are not delayed in transit from the grower to actual preparation, cannot be too strongly emphasized.

### Preparation

The same precautions against heating should be observed for this product as were described for green peas. The shelled beans are washed and sent to the blancher.

### Blanching

The usual blanching time in live steam is at least 2 to 4 minutes. (See Appendix.) Large seeded varieties may require slightly longer times. Blancher loads should not exceed 1 pound per square foot.

### Dehydration

If there is delay between blanching and dehydration, cooling, as for peas, should be practiced. Delay at this point should be less than ½ hour. Tray loading for dehydration should not exceed 1 pound per square foot. Entering temperature with counter-current system should be 135° F. and finishing temperature should not exceed 150° F. with wet bulb at 90° to 95° F. Final moisture should not be greater than 5 per cent. The drying ratio varies between 3 and 4 to 1. Use the two-stage drying system to speed drying.

## PACKAGING

All of the precautions observed in obtaining high quality—absolutely fresh raw materials, handling and preparing with skill and care, blanching properly, and dehydrating under closely controlled conditions—may come to naught if control and vigilance are relaxed following the dehydration procedure.

Packaging properly to prevent absorption of moisture and to exclude air, gas, insects, and rodents is as necessary as are careful manufacturing operations. The requirements for an ideal container to be used under severe conditions would include all of the following essential characteristics:

1. Airtight.
2. Waterproof.
3. Moisture-vapor proof.
4. Gasproof.
5. Insectproof.
6. Offer maximum protection against deterioration, from rust, corrosion, or structural breakdown, under a wide range of climatic conditions.
7. Ability to retain foregoing characteristics over longest possible time.

Only a hermetically sealed metal can is adequate to fulfill all of the characteristics listed above. Because of the need for conservation of steel, however, a substitute package has been developed by the Army for limited use. This package, called the three-in-one carton, is used for packaging those vegetables that do not absorb moisture too readily. It consists essentially of an inner fiber carton that is filled with the product and sealed. This carton is then inserted in a special envelope made of cellophane laminated to lead foil, which is in turn laminated with asphalt to kraft paper. This special envelope is heat-sealed and inserted into a weatherproof solid fiber outer carton. Still to be demonstrated is the complete suitability of this carton in field use.

The can manufacturing companies have developed a special square 5-gallon can to be used for packaging dehydrated fruits and vegetables. This can is furnished with a round opening to which a standard No. 10 end is double-seamed insuring a hermetic seal and simplifying gas-packing of such products as cabbage and carrots, which require storage in an inert atmosphere. Processors should endeavor to fill each can completely, but the pieces of dried product should not be crushed or broken.

Compression of dehydrated products is being investigated and, if the proper equipment is devised, the same weight of material that formerly required packaging in the 5-gallon size can will be packed in a No. 10 can.

Fruits, before packaging, usually should be subjected to live steam by passage through an exhaust box, or similar device, at 212° F. This practice will destroy insect eggs and rid the fruit of yeasts and molds whose growth and activity would impair the quality of the product during storage.

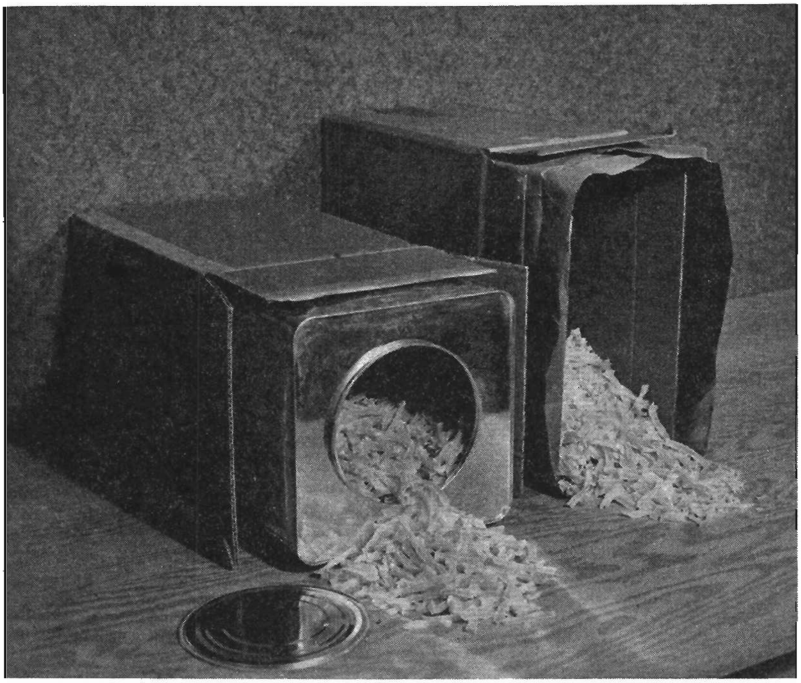

Figure 7. Accepted styles of containers for dehydrated vegetables for war contracts.

# Appendix

## ENZYME TESTING METHODS

Close control of the blanching operation is necessary to assure proper inactivation of enzymes while avoiding overblanching. The peroxidase system is one of the most heat-stable enzyme systems likely to be found in vegetable tissues. If it can be demonstrated that peroxidase has been destroyed, in most cases there can be assurance that other enzyme systems that contribute to deterioration of the product and destruction of nutritive principles during dehydration and storage will also have been inactivated.

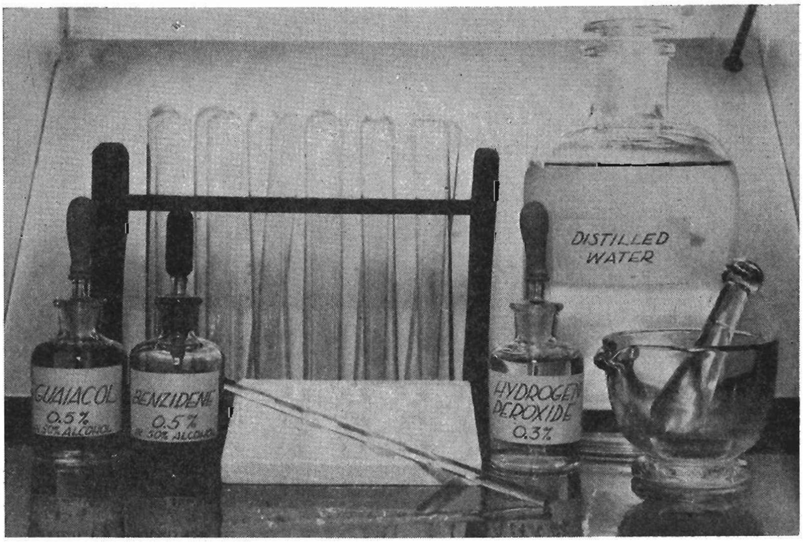


Figure 8. Equipment necessary for enzyme tests.

## TESTING FOR PEROXIDASE

The presence of peroxidase is determined by a method that is easily applied and highly sensitive. Either of two reagents may be used with equally satisfactory results. The test is conducted as follows:

A. GUAIACOL TEST

1. A small piece of the blanched material (2 to 3 g.) is placed in a test tube and 5 cc. of distilled water added. Using a clean glass stirring rod, the sample is broken up and well mixed with the water. The sample can be

mixed and ground with water in a small mortar, if it is available.

2. After allowing the solid matter to settle for a few minutes, the liquid is poured into a clean test tube or a small portion is placed in one of the depressions of a spot plate. (See Figure 8.) To this solution add 3 drops of 0.3 per cent hydrogen peroxide (reagent grade, not hydrogen peroxide sold in drug stores).
3. Add to the mixture 3 drops of 0.5 per cent solution of guaiacol in 50 per cent ethyl alcohol.
4. The presence of peroxidase will be indicated by development of a characteristic reddish color.

B. BENZIDINE TEST

1. Same as (1) above.
2. Same as (2) above.
3. Add to the mixture 3 drops of 0.5 per cent benzidine in 50 per cent ethyl alcohol.
4. Development of a characteristic blue color indicates presence of peroxidase.

C. WARNING

1. The peroxide commonly available in drug stores in 3 per cent concentration may contain acetanilid, which would render it unusable for the enzyme test. Keep hydrogen peroxide solution in a cool, dark place.
2. A thoroughly boiled portion and an unblanched portion of the material under examination should be tested and the time noted for development of the characteristic color in each case. This will allow a comparison of an unblanched portion with the blanched product. Ordinarily a color that develops in 2 or 3 minutes will indicate a high peroxidase content while the development of color in 10 to 15 minutes will denote a negligible amount of the enzyme.

## SULPHURING FRUITS

Exposure of fruits to the fumes of burning sulphur for a short or extended period is accepted practice in the pretreatment for fruit dehydration. An exposure of 30 minutes to 2 hours is designated as "light sulphuring." "Heavy sulphuring" may require exposures up to 24 hours in exceptional cases. Fruits that are intended for overseas shipment and storage under severe climatic conditions of heat and humidity should be very heavily sulphured to retard deterioration. Recommendations have been made that fruit for tropical storage be sulphured to 12,000 parts per million, or more. For domestic use 1,000 to 1,500 parts per million should be an adequate content of sulphur dioxide to protect the fruit under storage conditions likely to be encountered.

It is to be realized that there is a great loss of sulphur dioxide during the dehydration process. When a fresh fruit is sulphured to 1,000 ppm., however, and it is dehydrated to $\frac{1}{5}$ of its fruit weight it can lose 90 per cent of its $SO_2$ and still have a concentration of 500 ppm. in the dehydrated product. In instances where a very high sulphur content is required for tropical shipments, resulphuring before packaging must be practiced.

In the usual sulphuring treatment, the prepared fruit is spread on trays. The trays are loaded on the dehydrator car, which is then rolled into the sulphur house.

The sulphur house is a simple boxlike affair that may be of permanent brick, tile, concrete, or frame construction into which the car is rolled over a pit that accommodates the combustion pot in which the sulphur is burned. As an alternative, the house may be of light-frame construction covered with heavy asphalt sheathing paper, roofing, or some similar material. This second type of house, called a hood, is lowered over the loaded car after it has been placed in position above the pit. Regardless of the type of house used, it must be so made that it is free from leaks that would allow $SO_2$ to escape and air to enter but must have adjustable venting arrangements near the roof to allow entrance of sufficient air to burn the sulphur and provide circulation of the gases. In a properly constructed sulphur house the concentration of $SO_2$ gas should reach $2\frac{1}{2}$ per cent If this concentration is not obtainable, much longer sulphuring times may be required. Ordinarily 5 to 8 pounds of sulphur will be used per ton of fruit. This weight is not as important, however, as maintenance of the proper concentration of the fumes within the house.

One of the primary requirements for a successful sulphuring operation is the use of high-quality, arsenic-free sulphur. Protection of the sulphur from contamination by lubricating oil, charcoal, or debris of any kind, such as matches, is essential to proper combustion. It has been found that heating of the sulphur to the melting point before igniting materially reduces initial combustion difficulties.

## THE DETERMINATION OF MOISTURE CONTENT

In order to be certain that dehydrated products will meet federal specifications it will be necessary to employ some method, or methods, for determining the moisture content of the product. The method officially specified is that given in *Methods of Analysis of the Association of Official Agricultural Chemists* (1940), page 336. This method employs the vacuum oven and requires 6 hours for its completion. Further, the method is empirical in that the operator must adhere strictly to the conditions prescribed in order to obtain reproducible results. Obviously, the time factor is also a handicap in commercial operation.

Unfortunately, there is no good, easy, rapid method of determining moisture. Methods have been developed, however, which, at the sacrifice of some accuracy, require less time. In each case the method used must be standardized against the vacuum-oven method to learn the discrepancies involved. When this has been done, a careful operator may expect accuracies within the range of ½ per cent. Improper manipulation, however, may lead him far astray from the true moisture content of his product.

One rapid method that may be employed is the toluene or xylene distillation, described in *Methods of Analysis of the Association of Official Agricultural Chemists*, page 62, or as modified by this department and described in Oregon State College Experiment Station Circular 82. Descriptions of apparatus employing electrical principles, such as the Steinlite, Tag-Heppenstall, Moisture Register, and others of this type may be obtained from their manufacturers or from laboratory supply firms.