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COMMERCIAL DEHYDRATION

OF VEGETABLES
AND FRUITS
IN WARTIME

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UNDER THE STIMULUS of war needs, the production of dehydrated foods is becoming an important industry in the United States. Because they save shipping space and reduce weight, require less metal for containers, are economical, and keep well, these foods have a vital part in the war. Millions of pounds—practically all that can be produced—are now being sent abroad to our armed forces and our allies.

Farmers grow the foods that are dehydrated. This bulletin has been prepared to give them, and others interested in the process, an understanding of what is involved in the dehydration of vegetables and fruits and to answer such questions as: What kinds and varieties are best suited to dehydration? How are the products handled and dried in the dehydration plant? What are the requirements for packaging and storage? What are the proper ways of preparing them for the table?

Changes and improvements in methods are constantly being made as research continues and as the industry expands, and still better products will undoubtedly be produced as time goes on.

Commercial Dehydration of Vegetables and Fruits in Wartime¹

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THE IMPORTANCE OF DEHYDRATED FOODS IN THE WAR

FOOD AND MUNITIONS are war essentials. Fighting men must have both. The United States is supplying its armed forces all over the world with food and is also sending, under the Lend-Lease Act, millions of pounds of food for the civilian populations of some of our allies. Invasion of territories by our forces will bring increased demands for food. An immense total of foodstuffs will have to be shipped to all quarters of the globe.

It takes a great number of ships to carry this food and all the other things that must go with it. Not only is conservation of cargo space necessary, but also conservation of the metal used in food containers. Dehydration helps fulfill the triple requirement of more food in less space, packaged with less metal.

Almost all natural foods contain much water. Most fresh vegetables and fruits contain 75 to 95 percent of water. Dehydration—rapid artificial drying—reduces the moisture content to 3 to 7 percent. The

¹ This publication was prepared by Marion J. Drown, associate technical editor, from material supplied largely by the laboratories of the Agricultural Research Administration, which includes the Bureaus of Agricultural and Industrial Chemistry; Animal Industry; Dairy Industry; Entomology and Plant Quarantine; Human Nutrition and Home Economics; Plant Industry, Soils, and Agricultural Engineering; and the Office of Experiment Stations. In its recent work on dehydration, the Agricultural Research Administration has had the cooperation of numerous research agencies, both public and private, and this publication contains information from a wide range of sources. The Western Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry has carried on much pioneering work in the commercial dehydration of vegetables and fruits.

When the food is dehydrated one ship will carry as much as six

DEHYDRATED

NOT DEHYDRATED

FIGURE 1.—We can't afford to use precious ships to carry water around the world. It has been estimated that dehydrated foods, from which most of the water has been removed, can be shipped, on an average, in one-sixth of the cargo space required for fresh or canned foods of the same kind. Moreover, they do not require refrigeration.

volume of dehydrated vegetables roughly averages about one-sixth that of the original fresh products. This means that one ship or freight car or plane or truck can do the food-carrying job of six, while five are released for other vital transportation needs (fig. 1). Weight is reduced even more than bulk—to one-tenth of that of the raw product. This also is an important consideration, especially in shipping by air. No inedible material takes up space or adds to the weight of dehydrated foods, for tops, skins, cores, and seeds are removed before drying (fig. 2).

The requirement that less metal be used for containers is fulfilled by dehydrated foods mainly because of the great reduction in volume (fig. 3). A large proportion of the 5-gallon cans now chiefly used in shipping these foods may later be replaced by nonmetal substitute packages which are being developed.

In spite of the savings they effect in cargo space and strategic metal, there would be little use in sending dehydrated foods that were not appetizing and nutritious around the world to feed soldiers and hungry people. Dehydrated foods are attractive in appearance, have a pleasing taste, and supply many of the important nutritive elements.

DEHYDRATION, OLD AND NEW

"Dehydration" is merely another word for drying, or the removal of water, but as used today it means drying foods quickly under controlled conditions of temperature, humidity, and air flow so that their color and flavor are retained and their cellular structure is not dam-

aged. Food thus scientifically dehydrated can be brought back to approximately its fresh condition by being soaked in water, which it readily absorbs, and can be kept for long periods if protected by proper packaging. The moisture content of the new dehydrated vegetables ranges from 3 to 7 percent, in contrast to 10 to 25 percent in sun-dried or home-dried products and at least 10 percent in foods dehydrated during the first World War. The advancement in the art of drying foods is the result of the combined investigations of horticulturists, chemists, physicists, engineers, nutritionists, home economists, plant breeders, and others.

Drying is probably the oldest form of food preservation. Cereals, nuts, and some fruits are dried by nature's own process. Sun-dried food was used by primitive man and in early civilizations. The

FIGURE 2.—A head of cabbage to be dehydrated is prepared by removing the outer leaves, trimming, coring, and shredding. Dehydration takes out most of the water—and raw cabbage is 88 to 95 percent water.

American Indians dried meat, corn, and fruits before white men came to this continent. The New England colonists dried codfish, corn, and berries, and later apples and other fruits. Drying codfish for export was the first commercial food industry of North America.

Many of the familiar dried fruits, such as prunes, raisins, apricots, and peaches, are sun-dried to a large extent, though artificial drying is gradually supplementing or displacing the older method. Most vegetables cannot be sun-dried successfully, as they begin to deteriorate before evaporation is well started.

IN FORMER WARS

Because they increase the need for preservation and transportation of foods, wars have often brought about innovations and improvements in food-processing methods. Early in the Napoleonic wars, the French Government offered a prize for the discovery of a new method of preserving food, and after years of work on the problem Nicolas Appert, a Paris confectioner, won the award with the process which has developed into modern canning.

The Civil War gave a great impetus to canning in this country. Also, according to a publication of the period, the Union troops were furnished with "desiccated vegetables" because they were believed to be "serviceable in arresting tendencies to scorbutic disease [scurvy],

and in promoting and preserving the general health." The author of this book,² after listing the percentages of water in the common vegetables, continues:

As desiccated vegetables, the water is in large part removed, the bulk correspondingly reduced, and the liability to injury from variations of heat and atmospheric moisture overcome. Potatoes, cabbages, turnips, carrots, parsnips, beets, tomatoes, onions, peas, beans, lentils, celery, &c., are thoroughly cleaned, sliced, dried in a current of heated air, weighed, seasoned, and pressed with the aid of a hydraulic press into compact forms, sealed in tin cases, and enclosed in

FIGURE 3.—Three crates of raw carrots can be reduced by dehydration to just enough to fill one 5-gallon can. This small pile, however, when it has soaked up enough water to restore it to nearly its original condition, will serve 600 men. The container shown is of the type in which dehydrated foods are commonly packed for shipment to our armed forces.

wooden boxes. In this condition they are sent to the field. An ounce is a ration. A block 1-foot square and 2 inches thick weighs 7 pounds, and contains vegetables for a single ration for 112 men. It requires only to be soaked in cold water and then sufficiently boiled, with a piece of meat, to make a savory and every way delicious soup. * * *

It is questionable how much of the vitamin content was retained in foods so dried and pressed. The existence of vitamins was of course unsuspected, but evidently the wartime advantages of dehydration were appreciated as far back as the 1860's.

During the Boer War, Great Britain sent large quantities of dried vegetable-soup mixture to South Africa. After 1900 Germany and other Central European countries made substantial advances in de-

² HORSFORD, E. N. THE ARMY RATION. 44 pp. New York. 1864. (See p. 11.)

hydration and used dehydrated vegetables to advantage in the first World War.

Nearly 9 million pounds of dehydrated foods, mainly potatoes and soup mixtures, were sent to the United States forces overseas in 1918. Some of this material was good, but much of it did not keep well. Army cooks were inexperienced and untrained in methods of preparing it (fig. 4), and it was not successful.

FIGURE 4.—In the last war dehydrated foods did not fulfill their purpose, partly because they were not properly prepared for eating. Now Army cooks are taught how to conserve flavor as well as food values by soaking the foods in the right amount of water and cooking them a short time just before serving.

Even before the war ended, the Department of Agriculture initiated a research program to develop methods for producing better dehydrated foods. The results of this research were published in *Farmers' Bulletin 984, Farm and Home Drying of Fruits and Vegetables*,³ published in 1918, and in *Department Bulletin 1335*, issued in 1925 (since revised as *Circular 619, Preservation of Fruits and Vegetables by Commercial Dehydration*). This work furnished the foundation for the investigations and commercial dehydration operations begun after the outbreak of the present war.

³ Out of print, but may be consulted in libraries.

SINCE 1940

The United States began to make intensive preparations for defense in 1940. On March 11, 1941, the Lend-Lease Act became a law. Under this act millions of pounds of agricultural commodities have been shipped to foreign nations.

When submarine sinkings began to reduce the number of allied ships, the need for large-scale methods of processing that would reduce the weight and bulk of foods became urgent. In June 1941 a committee on dehydration was appointed in the Bureau of Agricultural and Industrial Chemistry to formulate and get under way a research program for the purpose of improving dehydration methods. Other research agencies, including State agricultural experiment stations and laboratories in private industries, also began to assemble results of earlier research and to attempt to solve pressing problems. An active program of research on the commercial dehydration of foods is being carried on by several bureaus of the Agricultural Research Administration and by the agricultural experiment stations.

In the fall of 1942 the Department of Agriculture conducted two 2-week conferences, which were called dehydration training schools. The purpose of these sessions was to assist dehydrators to produce economically the best products possible and to establish a sound technical foundation for a permanent industry. One school was held at the Western Regional Research Laboratory, Albany, Calif., and the other at Rochester, N. Y. More than 250 persons actively engaged in commercial dehydration attended the two meetings. Through lectures, discussions, and demonstrations, the results of research and experience up to date were shared by research workers and the industry.

The dehydrated vegetables being purchased for the armed forces and lend-lease are mainly potatoes, cabbage, onions, carrots, beets, sweetpotatoes, and turnips, in addition to tomato juice, cranberry sauce, apple sauce, and soup mixtures. Many other vegetables and fruits, including sweet corn, peas, lima beans, string beans, broccoli, spinach and other greens, squash, tomatoes, and berries can be successfully dehydrated. Some of these may be more important after the war than those being produced in quantity for shipment abroad, since in the United States the root vegetables are usually obtainable in fresh form throughout the year. Dried potatoes and onions, however, give promise of becoming popular because they can be prepared more easily than the fresh products.

WHAT OF THE FUTURE?

The post-war future of the food dehydration industry, which under the stimulus of war is expanding so rapidly, depends on the cooperation of several groups in the United States. These are (1) the farmers, who grow the raw materials; (2) the processors, who, aided by the technical investigators, do the job of dehydrating; and (3) the civilian consumers, who will eventually have an opportunity to buy, cook, and eat the dehydrated foods.

Farmers, especially those whose lands are near a dehydration plant, can cooperate not only by producing the best products possible, but by growing the types and varieties best suited for dehydration.

Quality originates in the field. The Division of Fruit and Vegetable Crops and Diseases of the Bureau of Plant Industry, Soils, and Agricultural Engineering has made an intensive investigation of the suitability of different varieties of vegetables and fruits for dehydration. Recommended varieties of many of them will be found under the specific commodities in the section beginning on page 21.

The producers of dehydrated foods are striving to turn out high-quality products. Besides taking advantage of recent research findings, as shown by their cooperation in the dehydration schools just mentioned, they are conducting studies of their own and improving their methods as they gain experience.

FIGURE 5.—Fresh-looking green snap beans, mashed potatoes, carrots, corn, and a salad of dried peaches and pears—all dehydrated—make an appetizing meal with a meat cake added.

Everyone who eats belongs to the consumer group. With a few exceptions, dehydrated foods are not yet on the grocer's shelves, but when the total production no longer has to go to our armed forces and our allies more will be available for home use.

Housewives, who will buy and prepare the new foods, are especially interested in what may be expected of dehydrated products. "What do they look like?" "How do they taste?" "How do they compare with fresh, canned, or quick-frozen foods?" "Will they be expensive?" "Do they have the food values we need?" These are some of the questions that are being asked about dehydrated foods.

Dehydrated vegetables, even when dry, look good. They have the right colors—carrots are bright red-orange, spinach is a rich green, beets are deep red, sweet corn is creamy yellow. When they have been reconstituted, or rehydrated, by adding water, and cooked, they look just about like cooked fresh vegetables (fig. 5). People have eaten

meals of dehydrated foods without suspecting they were not fresh. Soup mixtures containing dehydrated vegetables have been on the market for some time, and many people use them regularly.

It is fairer to compare dehydrated foods with other processed foods than with fresh ones. No processed food is exactly like the fresh article straight from the garden. Some so-called fresh vegetables, however, have been in storage, in transit, or on shelves so long before reaching the table that less of their food value is left than is contained in canned, frozen, or dehydrated products the processing of which was begun a few hours after they were harvested. People have learned to like canned vegetables, though they seldom confuse them with fresh ones. Quick-frozen vegetables, too, have won popular acceptance. The same thing may be true of dehydrated foods.

There are several advantages to the housewife in the use of dehydrated foods. When she has to carry home the groceries she will appreciate the fact that a supply of dehydrated potatoes, carrots, cabbage, onions, string beans, peas, and apples weighs only a fraction as much as the same amount of fresh food. She will also welcome being freed from such work as peeling potatoes and onions and shelling peas. She can shake some dehydrated potato into a pan of water, boil it for 10 minutes, and serve a dish of fluffy mashed potatoes. The carrots are already sliced or diced; the cabbage is shredded. Kitchen preparation is reduced to a minimum.

The price per pound of dehydrated foods may seem high as compared with that of fresh or canned vegetables, but it should be remembered that only a few ounces of the dried product produce a pound of edible food when water has been added. No money is paid for waste material such as skins, cores, shells, tops, or defective parts. The amounts, in ounces, of some of the common vegetables dried to a 5-percent moisture content that will make a pound are as follows:

	Ounces		Ounces
Carrots.....	2	Spinach.....	2½-4
Beets.....	2½	Sweetpotatoes.....	4-5
Onions.....	2½	White potatoes.....	5
Cabbage.....	2½-4		

To serve four persons, 3 ounces of dehydrated white potatoes, 2 ounces of beets, carrots, onions, or sweetpotatoes, and only 1 ounce of cabbage or spinach are sufficient.

There are national economic benefits to be had from the use of dehydrated foods. This is a big country, and reducing the bulk and weight of some food shipments would help to relieve the domestic transportation load.

Marketing also is an important consideration, but it is not taken up in this publication, which deals chiefly with production and use of commercially dehydrated vegetables and fruits. The information given on use and preparation applies equally well to home-dried products, and to products dried in community food-preservation centers.

The question of the vitamin values of dehydrated foods is discussed under Retention of Nutritive Values, page 19.

PROBLEMS AND METHODS OF VEGETABLE AND FRUIT DEHYDRATION

LOCATION OF THE DEHYDRATION PLANT

Vegetables and fruits are dehydrated in the regions of greatest production. Though many commodities are grown generally over the country, heavy commercial production is likely to be limited to certain districts. Even within a State, wide variation in concentration commonly occurs; certain valleys in the Pacific Coast States, for example, are noted for particular fruits or vegetables. Commercial sweet corn production is largely restricted to States around the Great Lakes, Maryland, New York, and Maine. Cranberries are limited to Massachusetts, New Jersey, Wisconsin, Washington, and Oregon. Figs are grown extensively only in California and Texas; onions are widely distributed over the country. Potatoes are grown almost everywhere in the United States, but heaviest production is in the Northern States. Sweetpotatoes are a southern crop, for the most part, although they are grown in quantity on the eastern seaboard as far north as New Jersey. Table beets are produced commercially in three well-defined areas located roughly in the northeastern, south central, and northwestern parts of the country.

Within the region best suited for the production of a selected vegetable or fruit, the particular location of the dehydration plant—its nearness to the fields where suitable products are grown—is of prime importance.

Additional factors that affect the location of plants, some of which are related to the present wartime emergency, are: (1) Suitability of existing food-processing plants for expansion or conversion to vegetable dehydration with minimum use of critical materials; (2) availability of experienced management and labor; (3) possibility of obtaining labor for production and harvesting; (4) satisfactory financial arrangements; (5) availability of controllable heat (steam, gas, or oil), electric power, pure water, and sewage facilities.

SELECTION OF CROPS AND VARIETIES

Not only climate and soil but also the variety and the strain within a variety of any given crop may affect the quality of finished dehydrated products. As a result, the food processor considers the adaptability of raw materials to dehydration as well as modifications of his technique to make the best possible product from the raw material available.

A vegetable or fruit of a certain variety grown in one region will frequently be distinctly different as a finished dehydrated product from one of the same variety grown in another region. This is a matter for consideration within the various regions; experience and study, with consequent adaptation of processes and the selection of suitable varieties and types of crop, will aid the farmer and the processor. Certain general statements are sound guides, however. The best type of white potato for dehydration, for example, becomes light and mealy rather than discolored and soggy when cooked. The more pungent white or yellow onions, carrots with deep-orange cores, and

dark-red beets of solid color are preferable and are called for in Government specifications. With fruits and certain vegetables, particularly those having easily recognized varieties such as apples and potatoes, the question of variety is extremely important. The varieties listed under Special Information on Individual Products (p. 21) have the general characteristics that make them satisfactory for dehydration.

Cooperation between producer and processor is advantageous. Contracts for the production of specified acreages of products of specific varieties and strains grown in accordance with the best farming practices are often desirable. Field men representing the factory are helpful both to the company and to the farmer. In making plans, certain principles of agricultural economy are important, especially during wartime; for example, production per acre and per man-hour of labor require careful consideration. Where harvest labor is difficult to obtain, time of harvest is important as a matter of labor distribution as well as of plant operation.

One of the most important factors is quality, which in vegetables and fruits includes taste and aroma, color, stage of maturity, and freedom from disease and blemish, as well as adaptability to dehydration. At best, processing of any kind can only conserve the original constituents of the food and develop some of its desirable characteristics.

HARVESTING AND DELIVERY TO THE PLANT

The best stage for harvesting vegetables and fruits that are to be dehydrated is, generally speaking, the prime stage for use of the particular product. There should be no evidence of decay, mold, or other deterioration.

Certain root crops, such as potatoes, carrots, and onions, can be stored for varying periods between harvest and processing, depending upon stage of maturity, variety, and storage temperature and conditions. Apples and pears stored for a few weeks at 36°–40° F. will retain or even improve their quality, but they should not be allowed to become soft.

For vegetables such as corn, beans, peas, spinach, and beets, the time between harvest and dehydration must be as short as possible. There is danger from bruising and cracking, with consequent molding and decay; from the spread of plant diseases; and from the heating that occurs in boxes, sacks, trucks, and cars of fresh material during long hauls. If delays are likely to occur, provision for cooling and storage is essential. If more than a brief delay is necessary, the vegetables must be stored at about 40° F. or packed in crushed ice. Even then they should not be held for longer than 12 to 16 hours.

For many vegetables and fruits the best storage temperature is between 40° and 50° F. Aeration, moderate humidity, cleanliness, and absence of light are also important in storage. The initial problem is often one of reducing the temperature of the fresh product. Icing and holding in cold running water are common methods. Vegetables and fruits are stored in refrigerated warehouses, in cellars, and in bins, and they are sometimes cooled by ice or water while in transit in trucks or railway cars. Storage under the best conditions, however, is a poor substitute for quick delivery from the field directly to the

dehydration plant. Delays at any point endanger quality. While vegetables and fruits are held in bins, boxes, or sacks, deteriorative processes set in within their tissues, robbing them of color, flavor, and nutritive values. High temperatures speed up this spoiling.

PREPARATION OF PRODUCTS FOR DEHYDRATION

The preparation of vegetables and fruits for dehydration is as important as the drying process itself. Speed, cleanliness, and efficiency are all-important. Most products are washed; graded; peeled; trimmed; cored or pitted; sliced, cubed, shredded, halved, or otherwise divided; washed again; and blanched just before they are dehydrated. These steps are modified for some commodities; onions, for example, are not blanched, and beets are cooked before they are cut.

In modern food-processing plants most of the preparation processes are performed mechanically. Conveyors move the products. A cylinder equipped with water sprays is commonly used as a washer. Products are mechanically graded into lots of uniform size so that they can be peeled and handled more economically. The essential feature of one type of grader is a vibrating plate with holes of different sizes. Round or approximately round commodities are rolled over slots of increasing width or over revolving rolls spaced at various distances.

Peeling is done in a number of ways. In the abrasive peeler a revolving carborundum or rough cement surface grinds off the skins, and running water carries away the scrapings. Hot lye is sometimes used for peeling carrots, potatoes, and sweetpotatoes; the lye is immediately washed off with water. The hot lye treatment also cleans out eyes in white potatoes, thus considerably reducing the labor of trimming. Dipping in hot saturated brine (salt water) loosens the skins of potatoes and certain other root vegetables so that they can be readily removed by vigorous mechanical scrubbing and washing by sprays of water; this method of peeling is being recommended for trial. Scalding water loosens the skins of tomatoes, beets, and certain fruits. Flame or radiant-heat peeling may be used for root crops; the intense heat chars the skin, and the char is removed by mechanical brushes and high-pressure water sprays. Some vegetables and fruits are peeled with rotating knives and some by hand. Others do not require peeling; cabbage, for example, is trimmed and cored.

Hand labor is required to a considerable extent for pitting, trimming (fig. 6), and final inspection, but dividing, or cutting into pieces, is usually done mechanically. Various types of machines are used for this purpose. The type is not important if the machine is efficient in operation, is readily cleaned, and in conjunction with other equipment maintains a steady and rapid flow of material through the plant.

Operators must make sure that the products flow steadily and are not allowed to collect in places where they are not kept in motion, since delay may cause spoilage. Equipment and tools and the bins, sacks, and boxes in which the raw products are handled require frequent and thorough cleaning. Large quantities of water are required in the preparation of food for processing—as much as 2,000 to 5,000 gallons per ton of raw product. An abundant supply of good water,

frequently tested, is necessary. Sewage disposal must be adequate. In well-managed food-processing plants some employees should be assigned solely to cleaning operations. Strict cleanliness on the part of all who handle the foods is necessary.

BLANCHING

Nearly all vegetables are blanched, or partially cooked, immediately after they are prepared and just before they are dehydrated. The word "blanch" means to whiten, and for that reason "scald" is possibly a more appropriate term, since blanching in this sense preserves color instead of bleaching it out. "Scald," however, implies the use of hot water, and although hot water is effective, it is likely to reduce the amounts of water-soluble nutritive factors such as vitamin C, the B vitamins, and minerals. Steam blanching is therefore recommended and is widely used.

FIGURE 6.—These carrots have already been mechanically washed and peeled. As the conveyor belt carries them along, the women cut off ends and trim out flaws.

The value of blanching has come to be more fully appreciated in recent years. Although the mechanism of its action is not completely understood, it is known that it results in much better retention of vitamins, flavor, and color throughout the dehydration process and subsequent storage than dehydrating without blanching. Blanching inactivates certain enzymes, increases the ease of rehydration of some products, destroys bacteria, molds, and other microscopic organisms, and causes other changes which need further study.

Blanching must be carried out quickly and thoroughly. If prepared food cannot be blanched immediately, it should be held under cool running water or in a 1- or 2-percent salt solution. One hour is the maximum time it should be held.

Fruits are not usually blanched but may be treated with sulfur to keep them from darkening and for other purposes. (See p. 19 for a discussion of sulfuring.)

Equipment for blanching may be a small tunnel through which material is conveyed on a wire-screen belt. Live steam in the tunnel partly cooks the food material as it passes through. Blanching can also be done on trays stacked in a stationary steam cabinet.

The temperature of live steam at atmospheric pressure (about 212° F.) is usually maintained in the blancher. The vegetables themselves should attain a temperature of at least 190° F. Some products require longer blanching and some a higher temperature than others. The plant operator can determine by certain chemical tests whether his blanching operation is effective and can make adjustments accordingly. Government specifications set up standards for blanching.

THE DRYING PROCESS

A piece of vegetable or fruit is in many respects like a small fine-grained sponge full of water. It is far more complex in structure, but for the first few minutes in the dehydrator it dries just as a wet sponge would. Evaporation is at first entirely from the surface and is very rapid. Later, water must move from the center to the surface, and drying becomes slower. As water comes to the surface and evaporates, the concentration of salts and sugars in the juice increases. In general, the hotter and drier the air and the more rapidly it circulates in the dehydrator, the faster the moisture will be drawn to the surface and evaporate. Too rapid drying may result in the formation of an impervious surface, with moisture trapped inside. This condition, called case-hardening, is more likely to occur with fruits than with vegetables. It may be prevented by controlling the rate of drying. Too high a temperature may also cause scorching. Food should be spread on the drying trays evenly and in a shallow layer to insure uniform drying. The new dehydration methods are more successful than previous ones because a lower moisture content is reached.

TYPES OF DEHYDRATORS

There are several types of dehydrators. For cut materials or whole small fruits, the tunnel and cabinet driers are most commonly used. The chief difference between these two types is that in the tunnel drier (fig. 7) the trays of food are loaded on trucks that move from one end to the other, whereas in the cabinet the trays remain stationary. The trays have wire-screen or wooden-slat bottoms, and currents of heated air circulated between and through them evaporate the moisture from the food.

The kind of raw material and the quantity available, the availability and cost of building materials, and other factors affect the design and construction of dehydrators. As a result of study and experience, improvements are constantly being made.

The tunnel drier is well suited to continuous operation and is economical in the use of heat. A single well-designed machine of this type will dehydrate 15 to 25 tons of raw material during a 24-hour run. For greater economy, tunnels are often constructed in groups of two or more.

There are several types of tunnel driers. In the parallel-flow, the counter-flow, and the center-exhaust types the food, piled on trays, is moved on trucks through the tunnel. In the parallel-flow type, the air current moves in the same direction as the trucks. The hot air enters at the same end as the food—the “wet” end—and is removed at the “dry” end, so that the fresh, damp material is in contact with the hottest and driest air. At the dry end, however, the air is not only cooler but is more or less saturated with the moisture taken up from the product. In the counter-flow drier these con-

FIGURE 7.—Tunnel dehydrator used for experimental studies in the Western Regional Research Laboratory, Albany, Calif. Trucks carrying trays of prepared food move on the track through the center. This dehydrator is equipped with instruments that permit studies of such factors as relative humidity, velocity, and temperature of the air.

ditions are reversed: the hottest and driest air enters at the dry end, and the wet end is in contact with the cooler and partly saturated air. The center-exhaust type is superseding the other two. In this drier, two streams of air are used, one moving from each end. Usually a partition of canvas or other material separates the two ends and is lifted only when the trucks are moved forward. This arrangement permits closer regulation of temperature and humidity.

In another type of tunnel drier, a large moving belt conveys the food from one end to the other, and the circulating air passes through the belt and the layer of food.

The cabinet dehydrator is a single compartment or series of compartments in which the trays remain stationary during drying. It

affords better opportunity to regulate humidity and temperature than the tunnel types. It is suited to smaller volume and noncontinuous use and is less economical of heat than the tunnel. It is especially useful where shortage of labor makes 24-hour operation impossible or where the available volume of raw material is insufficient to justify large-scale operation.

Vacuum drying is used for various types of materials, especially those that dry best at low temperature or with minimum exposure to air. In the vacuum dehydrator moisture is removed from the food in a chamber from which nearly all the air has been exhausted. Vacuum driers require much metal and are more complicated than other types. The method is used largely to "ultradry" certain foods from which most of the water has already been evaporated by other means.

There are driers of other types for handling materials that have been liquefied, pulped, pureed, or finely ground. In spray drying, liquid material is sprayed into a chamber through which a current of hot air moves, taking away the moisture and reducing the solid matter to a powder. Large quantities of spray-dried milk and eggs are being sent to the armed forces and to lend-lease nations. Certain fruit and vegetable juices can also be spray-dried, and though production is now small, research and experience may show the way toward quantity production and better quality of such products.

Pulpy matter and meat may be dried on a hot drum from which the dried material is scraped in flakes. Tomato flakes, cranberry flakes, and similar products are being made by the drum-drying method. Like other methods of dehydration, spray and drum drying are being studied and are developing rapidly.

DRYING TEMPERATURES AND LENGTH OF DRYING PERIOD

Drying follows immediately after blanching. In the tunnel and cabinet methods the damp, partly cooked material is spread on trays so that the warm dry air of the dehydrator can reach as much of the surface of each piece as possible. This means that trays must not be overloaded (fig. 8).

Temperatures of air, rates of air movement, and length of time required to complete the drying vary widely with the method used and the material. Some products take longer to dry than others, but the usual range is between 3 and 8 hours. The initial temperatures may be as high as 220° F. for certain foods, but the temperature at the end of the drying period is usually 40° to 80° lower. As high an air velocity as can be attained economically and as high a temperature as can be used without scorching or otherwise injuring the product are recommended. Vitamin C retention has been found to be better in hot, rapid drying than in slower, cooler drying.

The dried food is sometimes removed from the trays and placed in finishing, or curing, bins, where a uniform moisture content of the entire mass is attained. Food containing 7 to 15 percent of moisture may be dried in finishing bins to a 5-percent moisture content by a slow movement of air at 110° to 120° F. From the bins the dehydrated food goes into the packages.

PACKAGING AND STORAGE

The packaging of dehydrated foods presents many problems. The dry material is normally surrounded by air in the package. Air contains oxygen, and the presence of oxygen in containers may result in oxidation of the food. This is a deteriorative process that varies in rate with the commodity, its moisture content, the temperature, length of time the product is kept in the package, and other conditions. Oxidation may cause loss of color, flavor, and nutritive value. Some dehydrated foods keep well in air; others require that air be excluded almost completely.

FIGURE 8.—Shredded cabbage carefully spread on trays which are being piled up ready to go into the drier.

Replacing the air in a package of food with an inert gas—in this case, one that contains little or no free oxygen—has been found to retard the loss of desirable factors in certain dehydrated foods that are particularly subject to oxidation. Studies have shown that inert-gas atmospheres are especially necessary for carrots and cabbage. Specifications for Government purchase require gas packing for these two vegetables.

The inert gases recommended are carbon dioxide and nitrogen. The carbon dioxide is usually preferred because it is less expensive than nitrogen. The air in the package is replaced with gas in various ways. The can of food may be placed in an airtight chamber and the air exhausted; when a high vacuum is reached the gas is allowed to flow into the chamber and fill the can, which is then sealed. Another

method consists in inserting a tube from a cylinder of gas into a can already filled with dehydrated food (fig. 9). A measured amount of gas flows through the tube, displaces the air, and fills the can in one operation. A can may be filled with carbon dioxide gas by placing an exact amount of finely ground solid carbon dioxide (dry ice) in the bottom just before the food is put in. Gas is generated directly from the solid material and pushes the air out of the can.

FIGURE 9.—Replacing air in a can of dehydrated cabbage with an inert gas, which flows through the tube to the bottom of the can. The gas atmosphere prevents oxidation, which would result in loss of color, flavor, and vitamins.

Packages for dehydrated foods must keep the contents dry by excluding water and moisture vapor, must keep out insects and protect from damage by rodents, must be easily sealed, and must stand up under rough handling—an especially important point in shipments to battle fronts. The common "tin" can, which is composed almost entirely of steel, fulfills all these conditions. Substitute packaging materials being tested are paper treated to resist moisture vapor; moistureproof cellophane; simple laminations of paper and cellophane; and compound laminations of paper, cellophane, and metallic foils. Containers made of these materials must be readily sealed by application of heat, free of such defects as pinholes and cracks, and heavy enough to withstand some hard knocks. None of those yet developed are absolutely moisture-vapor-proof.

The keeping quality of a dehydrated food is closely related to its degree of dryness. The objective in packaging and storage should be to maintain as low a moisture content as possible. Experiments with dehydrated cabbage stored at 90° F. have shown that storage life, measured by the retention of vitamin C, is increased 50 percent for

each 1 percent of decrease in moisture content. This relationship held over a range in moisture content of 12 percent to 3 percent. That is, within that range each successively lower percentage of moisture lengthened the storage life of the cabbage 50 percent. A similar relationship has been observed between palatability and moisture content of carrots during storage.

Moisture pick-up, or the moisture that accumulates within a package after it has been sealed, is not serious if it does not exceed 2 percent in a year. An increase in moisture no greater than that will not cause excessive deterioration. Measures that protect sealed and stored packages from high temperature and dampness are of value. Dehydrated vegetables and fruits—in fact all foods, fresh or packaged—keep better at low than at high temperatures.

Safeguards against insect infestation and damage by rodents are necessary. Foods leaving the dehydrator will remain free of insects if run directly into clean packages that are immediately sealed. If dehydrated foods are left exposed, insects may lay eggs on them, and unless they are heated again to 135° F. before being packaged, active infestation may be sealed in the package and ruin the product. If the food has become infested with insects, heat treatment will not make it fit to use. Insects cannot live in packages containing inert gas. Rodents are a constant threat to nonmetallic packages of food.

COMPRESSING DEHYDRATED VEGETABLES

Compressing dehydrated vegetables makes possible additional savings in space of 40 to 80 percent. It takes out most of the air and simplifies packaging. Pressures of 100 to 2,500 pounds per square inch are used.

Meat compresses more readily than other dried foods, and blocked (pressed) dehydrated pork is being purchased for lend-lease shipments. Compressing egg powder reduces the volume 30 percent.

Advances have been made in producing dehydrated carrots, rutabagas, onions, and beets in compressed form. Because of the possibilities of saving shipping space the Army and other agencies purchasing food for shipment abroad are much interested in these developments. Dried vegetable material, however, has a tendency to shatter under pressure at room temperature unless more moisture is present than is permissible in dehydrated vegetables. If material is compressed at a higher moisture content than 5 to 7 percent, it must be dried further, which takes a long time and is destructive of vitamins. Compression may break down the cell walls of starchy vegetables and cause release of starch, so that potatoes, for example, may have a pasty taste and consistency when reconstituted.

Research by both Government and commercial investigators is producing encouraging results. Applying pressure at 120°–165° F. shows promise of preventing the shattering of vegetables, and a method of dehydrating and compressing some products at freezing temperatures is attracting considerable interest.

DRYING AND SULFURING FRUITS

In areas of abundant sunshine and freedom from rain during and following the harvest season, such as are found chiefly in California, certain fruits are extensively sun-dried. Other fruits are artificially

dried; apples, for example, are not sun-dried commercially. Prunes and clingstone peaches may be either sun-dried or dehydrated, but freestone peaches, apricots, figs, pears, and nectarines are nearly always sun-dried, as are most raisin grapes, although considerable quantities of seedless grapes are now dehydrated. Dehydration of clingstone peaches and golden-bleached raisins is comparatively new. Increasing numbers of prunes and figs are being dehydrated.

Unlike most vegetables, fruits to be dried are rarely blanched in steam or hot water. Prunes and sometimes figs and grapes may be dipped in a hot lye solution as a means of checking (cracking) the skins to facilitate drying. The darker colored fruits—prunes and some varieties of grapes and figs—often are simply washed.

Preparation of the light-colored fruits usually includes sulfuring. Peaches, apricots, pears, apples, grapes for golden-bleached raisins, and some figs are sulfured. In this process the prepared fruits are exposed to the fumes of burning sulfur and absorb varying amounts of sulfur dioxide, which protects the color and makes other improvements in quality. Sulfur makes the cells more permeable, thus hastening drying, and helps to preserve ascorbic acid (vitamin C), though to a large extent it destroys thiamine (vitamin B₁).

Fruit is sulfured on trays in an enclosed chamber or small building, large enough, usually, to hold one or two loaded trucks. The sulfur is preferably burned in a shallow pan on the floor, and the trays are stacked one above the other in zigzag formation to facilitate the circulation of the fumes. Sulfuring should be as light as possible to accomplish the desired results.

Fruits are not generally dried to as low a moisture content as vegetables. The greater amount of sugar in fruit, though it aids keeping quality, increases the tendency to case-harden if drying is long continued at too fast a rate. Some fruit products, however, such as apple nuggets—dried apples ground and further dried under vacuum—are dried to a moisture content of 3 percent or lower. Fruit flakes and powders also have a very low moisture content.

RETENTION OF NUTRITIVE VALUES

Dehydrated vegetables and fruits supply practically as many calories as fresh ones, and they retain most of their mineral values. It is not possible, at the time of writing, to make any accurate general statement regarding the retention or loss of vitamins in dehydration. Only a comparatively few scattered studies have been made so far, and those mainly with products dehydrated under laboratory or pilot-plant conditions rather than in commercial plants. The figures from these few analyses show a wide range of losses. More extensive studies of vitamin losses in dehydrated products are under way, however, and when sufficient data are collected it will be possible to form a more accurate picture. Research will continue to stress the development of methods that will make it possible to retain the maximum amounts of vitamins.

Figures on losses in storage are even scantier than those on losses during dehydration itself. The indications are that they can be heavy under adverse conditions.

It should be remembered, of course, that practically all methods of food processing reduce the amounts of some of the vitamins in

food. Cooking also results in vitamin losses; and even storage of fresh products, especially over long periods or under unsuitable conditions, may reduce vitamin C content in particular. Vitamin C, or ascorbic acid, is the hardest to retain. It is easily lost on contact with the air, and it dissolves in water. It is more readily retained in an acid than in an alkaline medium; dried tomato flakes and spray-dried citrus juices retain satisfactory amounts.

On the basis of experience so far, it may be said that it is of primary importance that containers for dehydrated foods should be airtight and keep the foods dry. Use of an inert gas in the container is important in controlling loss of carotene and vitamin C. Low-temperature storage slows down changes that result in vitamin losses. An adequate blanch is necessary to reduce subsequent losses of carotene and vitamin C in stored dehydrated products.

RECONSTITUTION AND COOKING

Replacing water in a dehydrated vegetable or fruit is known as reconstituting, rehydrating, or, sometimes, refreshing it. A properly dried product, when placed in water, soaks it up and returns to approximately its original form and texture.

The success of the rehydration process depends on many factors, including the quality of the material, the amount of liquid added, the composition of the liquid, and the length of time the food is soaked or boiled in it.

The Bureau of Human Nutrition and Home Economics has carried on experiments in cooking dehydrated foods and has also conducted research on methods of drying foods in home driers.⁴ Reconstituting and cooking methods for dehydrated vegetables have also been thoroughly tested at the Western Regional Research Laboratory.

General principles to keep in mind in cooking dehydrated vegetables are: (1) Soak them only until they are plump, or cook them without soaking; (2) cook them in the same water in which they are soaked; (3) simmer rather than boil; (4) cook only until tender; and (5) use any left-over cooking water. Cooked dehydrated vegetables are seasoned and served exactly like cooked fresh vegetables. Salt may be added during soaking, while cooking, or just before serving.

Some dehydrated vegetables are improved by being soaked before being cooked. Length of soaking time depends largely on the kind of vegetable and the size of the pieces. Whole snap beans may need to be soaked for 6 hours, while the same beans cut or sliced need soak only 2 hours. Some young, thin-podded beans which have been thoroughly cooked before drying need not be soaked at all.

Other dehydrated vegetables require no soaking before being cooked. Leafy vegetables, such as spinach, kale, beet greens, and turnip greens, may be dropped directly into a pan of boiling salted water and cooked with the cover on until tender. Almost any shredded, finely cut, or powdered vegetable can be cooked without preliminary soaking.

The soaking water may be hot or cold and should cover the dried material. Any floating pieces should be pushed down into the water.

⁴ For instructions on home drying see Farmers' Bulletin 1918, Drying Foods for Victory Meals.

Long soaking results in loss of flavor and aroma and may provide an opportunity for bacterial growth. Few vegetables need to be soaked more than an hour.

When vegetables have been soaked sufficiently they should be simmered in the same water in a covered pan until tender. Stir them occasionally to keep them from sticking, and add more water when necessary to prevent scorching. Five to 30 minutes' cooking is usually sufficient.

The cooking water from some dehydrated vegetables may be so strong as to be unpalatable, though the flavor of the vegetable itself is satisfactory. In spite of this, because some of the valuable nutrients are dissolved into the liquid, this water should not be discarded. It can often be used to advantage in sauces, soups, or gravies.

The rules for cooking dried fruits are slightly different from those for cooking dried vegetables. Two cups of dried fruit to 3 to 4 cups of water will usually be enough for six servings. Wash the fruit and soak about 1 hour or longer if it is very hard and dry. Thinly sliced dried apples and apple flakes, however, may require no soaking at all. Too long soaking draws out the flavor. Simmer 10 to 30 minutes or until tender.

The number of cupfuls of water required for reconstituting a cup of dried product is given in the next section under the individual commodities. If the amount of liquid recommended does not make a pleasantly moist product, add enough to bring it to that condition. The boiling time given in each instance is the minimum time. If a softer, more tender product is desired, the time should be increased, but boiling too long causes deterioration in taste, flavor, and color and excessive vitamin loss.

SPECIAL INFORMATION ON INDIVIDUAL PRODUCTS

In this section will be found information on varieties suitable for dehydration, a brief description of dehydration methods, and directions for reconstituting some of the more common vegetables and fruits. Details of preparation of these vegetables and fruits for drying apply to commercial dehydration and not to home drying.

Vegetables are dried to a 5-percent moisture content unless otherwise indicated.

The amount of liquid to use for reconstitution and the length of time to soak and cook are given for those products for which such data have been determined in the laboratory. In preparing foods the recommendations should be adapted to the recipe used. Time of boiling will vary with the softness of texture desired; the time given here is the minimum necessary to yield a satisfactory product. In general, dried food soaked for an hour before cooking will be plumper than when cooked without soaking.

VEGETABLES

BEANS, GREEN LIMA

Varieties of lima beans of the Henderson Bush and Fordhook types are satisfactory for dehydration. The beans should be light green and well-developed when harvested.

Lima beans are shelled and sorted to remove overmature white beans, washed, blanched in live steam 5 to 10 minutes, and cooled in water before being dried. The finishing temperature in the dehydrator should not exceed 150° F.

To reconstitute, boil 1 cup of large whole lima beans in 2 cups of water for 30 minutes.

BEANS, GREEN SNAP

The ideal stage of maturity for harvesting snap beans to be dehydrated extends from the time the seeds have begun to bulge the pods perceptibly until they have attained about two-thirds of their maximum diameter. In studies conducted by the Division of Fruit and Vegetable Crops and Diseases, at Beltsville, Md., to determine varieties of snap beans best suited to dehydration, the Stringless Green Pod group and Dwarf Horticultural variety of the dwarf, or bush, type, and Lazy Wife of the pole type were found to be the best of those tested. Other satisfactory varieties are Bountiful, Stringless Valentine, and Stringless Kidney Wax. Blue Lake and Kentucky Wonder have made satisfactory products when dried at the Western Regional Research Laboratory but were mediocre to poor as grown and dried at Beltsville.

Preparations for drying snap beans include sorting and washing, snipping off the stem end, and cutting or breaking the beans into pieces 1 to 1½ inches long. They are blanched in live steam for 5 to 10 minutes and cooled in water before being dried.

To reconstitute, soak 1 cup of snap beans in 2 cups of water for 2 hours at 70° to 80° F.; then boil for 30 minutes.

BEETS

The beet is a cool-season crop that can be grown at some time during the year almost everywhere in the United States. Beets grown in the late fall are best for dehydration because the cool weather develops the desired uniform deep-red color. Varieties recommended are Detroit Dark Red, Morse Detroit, and Ohio Canner. Beets should be harvested before they have begun to develop woodiness.

Beets are blanched in live steam in the whole form for 30 to 40 minutes or until cooked through to the center. They are then peeled, trimmed, and cut into slices, cubes, or strips.

To reconstitute, simmer diced beets for 30 minutes in 1½ cups of water. Sliced beets require only 1 cup of water to 1 of dried product.

CABBAGE

The Danish, Domestic, and Pointed Head varieties of solid white cabbage dehydrate satisfactorily. The British Army has expressed a preference for Savoy and other green-leaved loose-headed types of cabbage because they look attractive when dehydrated, have a good flavor, and are higher in vitamins than the white types. They are not raised in large quantities in this country, however.

Cabbage is carefully trimmed to remove wilted or blighted leaves, but all good outer leaves are left, since they are richer in vitamin C than the inner ones. Cabbage is cored, washed, and cut into coarse shreds one-eighth to one-fourth inch wide. After shredding there

should be no delay before blanching, or vitamin C will be lost. Cabbage is blanched in live steam for 2 to 4 minutes and then cooled in water before being dehydrated. The finishing temperature must not exceed 140° to 145° F. Cabbage is dried to a 4-percent moisture content.

To reconstitute, soak shredded cabbage in 2 cups of water for 2 hours at 70° to 80° F. and use for cole slaw or simmer for 10 minutes. Cabbage may also be cooked without soaking.

CARROTS

Carrots intended for dehydration should be uniformly deep orange, with little difference in character and depth of color between the core and the outside. Red Core Chantenay fulfills this requirement and is the variety chiefly used for dehydration in the Eastern States. In the West, Imperator, a variety of carrot with fairly deep orange flesh, is considered suitable for drying and is grown extensively. Chantenay is also dehydrated. Other varieties that may be suitable for dehydrating in regions where they are adapted are Morse Bunching, Danvers, and Long Orange.

Carrots are ready to be harvested for drying when the color is deep and uniform but woodiness and toughness have not yet developed.

After being washed, carrots are peeled or scraped, trimmed, and cut into slices, cubes, or strips. The live-steam blanch lasts 4 to 8 minutes. The highest finishing temperature is 165° F.

To reconstitute diced carrots, boil 1 cup in 4 cups of water for 10 minutes. Carrot strips require 1 $\frac{3}{4}$ cups of water and 5 minutes' boiling. Sliced carrots are cooked for 20 minutes in 1 cup of water to each cup of dried product.

CORN, SWEET

The relation of stage of maturity and variety of sweet corn to its quality when dehydrated has been the subject of a careful study by the Division of Fruit and Vegetable Crops and Diseases. Many varieties differ little in flavor and suitability for dehydration if harvested when the kernels contain 72 to 73 percent of moisture and are tender and not starchy. Of yellow corns, which excel white corns in vitamin content, excellent varieties for dehydrating are Aristogold Bantam Evergreen, Bantam Evergreen (Golden Evergreen), Golden Cross Bantam, Sachem, and Soobred. Another group of yellow varieties very nearly as good includes Allegheny, Charlevoix, Golden Bantam, Golden Colonel, Golden Hybrid 2439, Ioana, Marcross, Spancross, Tendergold, Top Cross Whipple Yellow, and Tristate Hybrid.

Three white varieties are rated as best of the group of white corns and are of equal excellence: Narrow Grain (Maine style) Evergreen, Country Gentleman, and Silver Cross Evergreen. Close to these in quality are Narrow Grain Hybrid 26 x 15, Silver Cross Country Gentleman, Country Gentleman Hybrid 19 x 24, Country Gentleman Illinois Hybrid 8 x 6, Honey June, and Pontiac.

Golden Cross Bantam is a leading variety wherever sweet corn is grown east of the Rocky Mountains except in Maine, Wisconsin, Maryland, and parts of Iowa. Ioana is widely adapted throughout the same region, including Maryland, Wisconsin, and Iowa. Golden Hybrid 2439 is a favorite variety in New York and Maryland and is much

grown elsewhere. Country Gentleman, Narrow Grain Evergreen, and Stowell Evergreen have long been grown in most corn-producing States. More recent varieties which are relatively untried but have a wide range of adaptability are Tendergold, Allegheny, and Sachem. Aristogold Bantam Evergreen and Bantam Evergreen are also grown throughout the Eastern States.

Before dehydration, corn is husked, silked, and trimmed, and then blanched on the cob for 6 to 8 minutes in live steam. After the ears are cooled in water, the kernels are cut from the cob. The final drying temperature should not exceed 165° F.

To reconstitute, cook 1 cup of dried whole corn kernels in 1 cup of boiling water for 10 minutes.

ONIONS

The primary requirement for onions that are to be dehydrated is a high degree of pungency—a strong characteristic flavor. Mild onions, when dried, do not impart sufficient onion flavor to stews or meats with which they are used for seasoning. This requirement for “hot” varieties restricts production of onions for dehydration to the Northern States, except for Red Creole and White Creole varieties, which are grown almost exclusively in Louisiana. The most pungent variety of all, Australian Brown, is adapted only to the west coast. Ebenezer, Southport White Globe, and White Portugal are widely grown in northern onion-producing regions. Barnett, a variety of high pungency, is widely adapted but relatively little grown. A number of other suitable varieties are of lesser importance because adapted to cultivation only in restricted areas, as Mountain Danvers in Colorado and the most northern States and Ohio Yellow Globe in the muck soils of the Great Lakes region. Southport Yellow Globe, Yellow Globe Danvers, and Southport Red Globe are fairly widely grown in the Northern States but are somewhat less pungent than the other varieties named.

Onions are washed and peeled and the root base and top removed preparatory to dehydrating. They are not blanched. Slices one-eighth to one-fourth inch thick are dried to a 4-percent moisture content, the finishing temperature not to exceed 140° F.

To reconstitute, soak 1 cup of sliced dried onion in $\frac{1}{2}$ cup of water for 2 to 4 hours at room temperature. Boil 5 to 10 minutes.

PARSNIPS

Little is known concerning the differences in suitability of varieties of parsnips for dehydration. Good varieties are Hollow Crown, Guernsey, Long Dutch, Model, Offenham Market.

Parsnips are prepared for drying by being washed, peeled, and trimmed. They are then sliced, diced, or stripped, and blanched for 6 to 10 minutes in live steam. The finishing temperature should not exceed 160° F.

To reconstitute, boil 1 cup of thin-sliced dried parsnips in $1\frac{1}{2}$ cups of water for 10 minutes or until tender.

PEAS, GREEN

Any of the market-garden varieties of green peas, such as Laxtons Progress, Tall Alderman, Stratagem, and Tall Telephone, will make good dehydrated products.

Peas are shelled, washed, and blanched in live steam for 4 to 5 minutes. They are cooled in water before drying; the finishing temperature should not exceed 150° F.

To reconstitute medium-sized peas, boil 1 cup in 2½ cups of water for 20 to 30 minutes or until tender.

POTATOES

Potatoes (white) are grown to some extent in every State in the Union. Of the 30 varieties grown on 2,733,400 acres in 1941, 10 occupied 95 percent of the area. A comparative study of the suitability for dehydration of 20 varieties was made by the Division of Fruit and Vegetable Crops and Diseases in the fall and winter of 1942-43. All varieties making up as much as 1 percent of the commercial acreage were tested, as well as several promising recent introductions. Varieties were rated on color, flavor, consistency, and general desirability as a dehydrated product. There were variations in quality in the same variety when grown in different regions. The results were as follows:

Katahdin: Colorado, excellent; Maine, Idaho, Michigan, New York, very good; Pennsylvania, good; Washington, fair. Sebago: Maine, excellent; Michigan and Washington, very good; Pennsylvania, good; Idaho, fair. Chippewa: Maine, excellent; Pennsylvania, Idaho, Michigan, New York, very good. Green Mountain: Maine, Pennsylvania, New York, excellent; Michigan, very good. Sequoia: Maine, excellent; Pennsylvania, very good; Washington, good. Houma: Maine, excellent; Pennsylvania, very good; Idaho, good. Warba: Maine, excellent; Pennsylvania, good. Pontiac: Maine, excellent; Idaho, Michigan, Washington, good. Triumph: Maine and Colorado, excellent; Idaho, very good. Russet Rural: Pennsylvania and Michigan, excellent. Rural New Yorker: Pennsylvania, excellent; Colorado, good. Russet Burbank (also called Netted Gem, Idaho Baker, Klamath Russet, and other names): Idaho, excellent; Washington, very good. Mohawk: Maine, excellent. Pioneer Rural: New York, excellent. Red Warba: Maine, excellent. Irish Cobbler: Maine and Michigan, very good; Pennsylvania and Idaho, good. White Rose: Maine, very good; Washington, good. No. 46952: Maine, very good. Pawnee: Colorado, very good. Earlane No. 2: Maine, good; Pennsylvania, fair.

No one variety of potato was shown to be consistently superior for dehydrating throughout the region in which it is grown, and no one region produces potatoes of all varieties that are better for the purpose than those grown elsewhere. All present-day varieties are very good to excellent if grown in districts to which they are well adapted. Potatoes that are white and mealy after cooking are best for dehydrating.

Preparation for drying potatoes includes washing, trimming, and peeling. They are cut into slices, cubes, or strips, and blanched in

live steam for 5 to 10 minutes. Potatoes to be riced are thoroughly precooked and put through the ricer while hot.

To reconstitute, boil diced potatoes in $1\frac{1}{2}$ cups of water to 1 of dried product for 10 minutes. Potato strips are cooked for 5 minutes in $1\frac{1}{3}$ cups of water. Riced potatoes should be soaked for half an hour in milk and water (half and half), $1\frac{1}{4}$ cups to 1 cup of potatoes, then heated for 10 minutes over boiling water.

RUTABAGAS

For dehydration the rutabaga variety American Purple Top is satisfactory, and Bangholm and Early Neckless are probably suitable also.

Rutabagas are washed, peeled or scraped, trimmed, and cut into slices, cubes, or strips. They are blanched in live steam for 5 to 10 minutes. Finishing temperature in the drier should not exceed 160° F.

To reconstitute diced rutabagas, soak 1 cup for 1 hour in $3\frac{1}{2}$ cups of water; sliced rutabagas are soaked in 2 cups of water for 1 hour. After soaking, boil for 20 minutes or until tender.

SPINACH AND OTHER GREENS

No specific recommendations of varieties of greens suitable for dehydration can be made on the basis of information now available. Varieties commonly used in the fresh form have been satisfactorily dehydrated.

Greens are prepared for dehydration by first removing the stems and discarding wilted, discolored, and blighted leaves. Then they are washed thoroughly and blanched in live steam. Blanching time is 2 to 3 minutes for spinach and mustard greens and 3 to 4 minutes for kale and Swiss chard. The finishing temperature in the drier should not exceed 180° F., and the final moisture content is 4 percent.

To reconstitute, cover with water and cook slowly for about 10 minutes or until tender.

SWEETPOTATOES

The qualities that make a sweetpotato satisfactory as a dehydrated product are good, well-defined flavor and smooth texture. Also, they should not be tough, starchy, or fibrous and should have an attractive, durable color, high carotene content, and good shape. Studies of the suitability of a large number of varieties of sweetpotatoes made by the Division of Fruit and Vegetable Crops and Diseases resulted in the following ratings with respect to the desirable qualities: Excellent: Nancy Hall and its selected strains, Nancy Gold, Meyers Early, and Mullihan; Orange Little Stem; Maryland Golden; and Mameyita. Very good: Porto Rico, Big Stem Jersey, Yellow Jersey, Yellow Strasburg, Red Bermuda. Good: Vineland Bush, Red Jersey, Gold Skin, Creola, Key West, Dooley, Pumpkin "Yam." The differences in palatability and table quality among these three groups are small, though they range in color from light yellow to deep orange.

The preparation of sweetpotatoes for dehydration differs somewhat from that of most other vegetables. They are washed, then steamed

for 5 to 10 minutes before being peeled. After they have been peeled and cut into slices, cubes, or strips, the pieces are held in water or a 1- to 2-percent citric acid solution, which removes starch from the cut surfaces. Length of blanching time is 6 to 10 minutes. Sweetpotatoes are dried to 7 percent moisture content or less.

To reconstitute these types of sweetpotato, boil 1 cup of the dried sliced product in 3 cups of water for 30 minutes or until tender.

TOMATOES

Firm-fleshed varieties of tomatoes such as Globe, Marglobe, Early Detroit, Greater Baltimore, Stone, and Santa Clara are recommended for dehydration.

Tomatoes are washed, dipped in boiling water, peeled, and any defects cut out. Slices one-fourth inch thick are blanched in live steam for 2 to 3 minutes. The finishing temperature should not exceed 150° F.

To reconstitute, add 1 cup of dried tomato slices to three-fourths of a cup of water, and boil gently for 5 minutes.

Tomatoes are more often pureed and dried on a drum drier, or the juice is spray-dried.

FRUITS

APPLES

Dried, or evaporated, apples have long been a staple commercial product. Locally grown varieties which it is not profitable to sell in the fresh market or culls of market varieties are chiefly used for drying. The principal requirements are good appearance, a minimum diameter of 2¼ inches, and other factors not connected with nutritive value, flavor, or palatability. Commercial grades are at present based on color, the whitest apples being rated highest. A better basis for grading would be inherent good quality or the quality of sauce, pie, or other products made from the dried fruit. Either of these standards would place such varieties as Winesap, Northern Spy, Stayman Winesap, and Esopus Spitzenberg in a preferred grade for drying.

The varieties chiefly used for drying in New York and Pennsylvania are Baldwin and Northern Spy; in Virginia and West Virginia, York Imperial, Winesap, and Stayman Winesap; in the Ozark region, Ben Davis and Winesap; in California, Yellow Newtown, Gravenstein, Yellow Bellflower, and Rhode Island Greening; and in Washington and Oregon, Jonathan, Delicious, Newtown, Rome Beauty, Winesap, Esopus Spitzenberg, and Grimes.

Apples of different varieties should not be run through the dehydration plant together, since they may differ in size and shape and in the amount of sulfuring necessary to prevent discoloration. Fruit should be stored carefully and not be held too long before it is dried.

Apples are prepared for drying by being washed, graded, pared, cored, cut, and sulfured. The finishing temperature should not exceed 160° F.

To reconstitute, follow the general directions given for fruits on page 21.

PEACHES

The dried peaches in the market are nearly all of two varieties, Muir and Lovell, which are extensively grown in certain sections of California especially for drying. Fruit of both varieties is freestone, uniformly yellow, dry, and mealy. When properly sulfured and dried in the sun, the product is translucent and golden yellow. Some other varieties are sun-dried in California to a lesser extent. Surpluses above the requirements of the fresh market and the canning industry are usually dried.

In recent years some peaches have been dehydrated in California. This method may come into greater use, but at present dehydrated peaches constitute only a small part of the annual production of dried peaches.

Freestone peaches grown in the Eastern States can be successfully dehydrated, but the product is different in appearance and flavor from the sun-dried California fruit. Eastern-grown fruit is more acid, contains less of the solids and sugars, varies more in color, and has a more pronounced flavor.

Varieties of freestone peaches grown in the East which, in tests of drying quality recently made at Beltsville, Md., by the Division of Fruit and Vegetable Crops and Diseases, were found to combine satisfactory texture, good to excellent flavor and palatability, and a fairly attractive color and appearance include Brackett, Elberta, Early Elberta, Eclipse, Early Crawford, Fay Elberta, Golden Jubilee, Halehaven, Halberta, Ideal, July Elberta, Kalamazoo, Kette, Lovell, Lemon Free, Late Crawford, Massasoit, Redelberta, Rio Oso Gem, Veteran, Valiant, and Viceroy. A second group similar in color and appearance, but not as good in flavor and texture when dried, includes J. H. Hale, Krummel, Oriole, Shippers Late Red, Salberta, Roberta, Rochester, Vedette, and Wilma.

Because of their tendency to discolor, most of the white-fleshed varieties tested contrasted unfavorably in appearance with the yellow varieties.

To have maximum sweetness, flavor, and texture, peaches to be dried should be allowed to become as ripe as possible without softening.

Most peaches are prepared for dehydration by immersion in a 9- to 10-percent lye solution at 140° F. for 3 to 5 minutes to loosen the skins; peelings and lye are washed off under jets of water. The peaches are halved, the stones removed, and the halves, stone side up, spread on trays for sulfuring. Steaming the fruit for 5 to 6 minutes before sulfuring will improve the color and general appearance, but this is not done commercially at present. Sulfuring takes 2 to 4 hours, depending on variety. The drying temperature should not exceed 140°-145° at the outset. After the fruit has lost about two-thirds of its moisture, the temperature should be reduced to 120°-125°, or else the relative humidity should be increased.

To reconstitute, follow the general directions for fruit given on page 21.

PEARS

Practically all the dried pears on the market are Bartlett pears sun-dried in California. Pears can be dehydrated, but they must

first be exposed to the sun for a day or be blanched for 15 to 20 minutes, and a rather long period of sulfuring is necessary. The temperature in the dehydrator should not exceed 145° – 150° F. at first, and it should be reduced when the fruit has lost most of its moisture.

Kieffer pears may be prepared and dehydrated in the same way if they are harvested while still hard and green and stored at 60° to 65° F. for 15 to 25 days. During storage the fruit softens and flavor and palatability improve.

The drying quality of Le Conte, Garber, Bosc, Anjou, and other varieties of relatively limited production has not been determined.

To reconstitute pears, follow the general directions for fruit given on page 21.

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