INVESTIGATIONS LEADING TO THE ESTABLISHMENT OF GRADES FOR DRIED FOODS

by

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A THESIS

submitted to the

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1941

APPROVED:

Head of Department of Food Industries
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ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Professor E. H. Wiegand under whose direction the work was undertaken; to Dr. E. W. Harvey for his suggestions during the investigation and his criticisms of the manuscript; to Associate Professor T. Onsdorff for his suggestions during the investigation; and to Professor W. V. Cruess, Director J. D. Mickle, Mr. C. H. Beasley, Dr. E. M. Mrak, and the many individuals and concerns in the dried food industry who furnished valuable data and suggestions upon which the standards given for the grades were based.

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INTRODUCTION

In the food industry, although standards have been established for canned goods, meats, and milk products, dried fruits and vegetables are still bought on sample. It is becoming evident, however, that a systematic and comprehensive set of standards will stimulate the dried food industry in making available in commonly understood terms such information concerning characteristics of the dried product as will permit their identification and comparison in the market. Such identification and comparison makes it possible for the consumer to secure the goods best suited to a particular use and with a minimum expenditure of time, effort, and money. With the establishment of standards the age old adage "Let the buyer beware" will no longer be the principle of trading.

Mr. Herbert Hoover, in his annual report as Secretary of Commerce in 1922, said "The lack of .... established grades and standards of quality adds very largely to the cost of distribution because of the necessity of buying and selling upon sample or otherwise, and because of the risk of fraud and misrepresentation, and consequently the larger margins of trading." With dried foods, this lack of established grades and standards has all its retarding effect on the industry and it is felt that standards and grades should be established.

However, the establishment of standards requires careful consideration. Standardization has been referred to in part as a process of securing information. In some cases the necessary information upon which standards are to be based is available; in many more cases such information is not at hand and must be obtained. Essential characteristics must be discovered and identified; methods and devices for measuring them must be developed.

It is recognized that securing the information essential to establishment of standards cannot be a haphazard process. It must be definitely planned and the field must be carefully surveyed as to the need and the information available. In this connection much literature on dried fruits and vegetables has been surveyed and comprehensive questionnaires have been sent out to the dried food industry. The purpose of this manuscript is to discuss the survey of the literature and to analyze the answers to the questionnaires sent back by the dried food industry so as to arrive at standards which might be beneficial to the industry.

PRINCIPLES OF DEHYDRATION

The purpose in view in drying any food material is to reduce its moisture content to such a point that the growth of organisms therein will be no longer possible and to stop the destructive activities of enzymes; and to do this with a minimum of alteration in the food value, appearance, and palatability of the product. The necessity for avoiding changes in physical appearance and chemical composition, other than actual loss of water, puts very definite limitations upon the means which may be employed to bring about drying and makes an understanding of certain principles a prerequisite to successful work.

It had been found that the more rapidly a material is dried the better the flavor of the product will be. Other advantages of rapid drying are that it minimizes opportunity for the growth of organisms and for the spontaneous chemical changes which set in as soon as the interior of the fruit is exposed to the air. Furthermore, a short drying period increases the drying capacity of the drying apparatus. However, it was also found that the lower the temperature the better the flavor, and in drying practice these two factors oppose each other. If, in order to get rapid drying, too high a temperature is used, the quality of the product is lowered. The optimum drying temperature to be used is therefore a compromise between the two opposing factors.

There are two possible ways in which drying may be accelerated besides raising the temperature, namely, by passing currents of air over the material, thus giving a large volume of air for absorbing and carrying away moisture, and by employing air which has previously had all moisture removed from it by passing through an air-drying apparatus. A theoretically perfect method of drying would combine all three means of hastening the process, and while such methods are in use in certain industries, they are impractical for drying fruits and vegetables because of their high cost.

Consequently, practical drying methods rely upon the use of heated air, with some means of maintaining the air in circulation over and through the product.

The moisture-carrying capacity of the air is a function of its temperature, and is practically doubled by every increase of 27 degrees in temperature. Therefore the application of a relatively moderate degree of heat brings about a very great increase in the air's capacity to absorb moisture. The temperature employed is consequently the most significant factor in determining the drying rate, and it is advisable to employ the highest temperature which can be used without injury to the product. The use of extreme temperatures in drying fruits and vegetables is impossible for three reasons: The various fruits and vegetables contain sixty-five to ninety per cent of water when prepared for drying. If such water-filled material were suddenly exposed to dry air having a temperature approaching that of boiling water, the rapid expansion of the fluids of the tissues would burst the cell membranes, thus permitting the loss of many of the soluble constituents of the product by dripping. Some decomposition of the sugars of the product would also occur at such temperatures, and the caramel (Caldwell 1917) formed would injure both the flavor and the appearance of the dry product. Furthermore, the very rapid drying of a thin layer at the surface of the material would occur, and this dry layer would retard the movement of water outward to the surface from the interior of the material, thus slowing down the drying process. This phenomenon is called case-hardening. The maximum temperature which can be employed without producing these injurious effects varies considerably with the different products, since it depends in every case upon the physical structure and chemical composition of the particular fruit or vegetable, but it is in all cases very considerably below the boiling point of water. The temperatures usually employed in the dehydration of fruits and vegetables are between 145 and 170 degrees Fahrenheit.

There must be a careful adjustment between the amount of heat applied and the volume of air passing through the apparatus. The heat required to convert the water evaporated from liquid to vapor is very considerable; the evaporation of one pound of water absorbs a quantity of heat which would reduce the temperature of 65,000 cubic feet of air by one degree Fahrenheit, or 1,000 cubic feet by 65 degrees Fahrenheit. It would seem that the greatest efficiency in a drying apparatus would be effected by allowing the heated air to expend most of its heat in vaporizing water and to permit it to become saturated before allowing it to escape from the dryer. This fact is not the case for several reasons. Air at any given temperature takes up moisture vapor quite rapidly until it has absorbed about half the quantity it is capable of carrying at that temperature, after which absorption goes on at a rapidly diminishing rate. At the same time, the air is losing heat through the vaporization of water, every reduction of 27 degrees Fahrenheit resulting in the loss of half its moisture-carrying capacity, this loss also operating to reduce the rate of absorption of moisture. Consequently, it is not practical to secure saturation of the air before allowing it to escape, as this would make the drying exceedingly slow. The best practice aims at permitting the air to vaporize and absorb such an amount of moisture as will reduce its temperature by not more than 25 to 35 degrees Fahrenheit during its passage through the apparatus, thus effecting rapid drying at the expense of the loss of about half of the theoretical drying efficiency of the heat used. As a matter of fact this heat is not wholly lost, since, with the latest type of dehydrator, the heated air is recirculated in part, and provision is made for the escape of the other part. Without such provision, the air cannot escape and will quickly become saturated, with the result that the escape of water vapor from the material is stopped and the product is cooked in its own juice. This fact is particularly true with juicy fruits such as prunes.

The relative degree of saturation of an atmosphere with moisture vapor is called its relative humidity. The relative humidity of air can only be taken in relation to temperature since hot air can take up much more moisture vapor than cool air. It is determined by the use of wet- and dry-bulb thermometers. The dry-bulb reading is the temperature of the air. The wet-bulb reading is a depressed reading due to the evaporation of moisture from the wet stocking surrounding the mercury bulb of the wet-bulb thermometer. The difference between the dry-bulb reading and the wet-bulb reading is called the wet bulb depression.

Relative humidity is calculated from the wet bulb depression by the use of a psychromatic chart or humidity table.

Taking the mechanism of dehydration as a whole it may be said that the rate of moisture removal is dependent on several factors which can be divided into two groups. One group embraces the physical properties of the material being dried and the other includes the external factors known as the drying conditions. Drying conditions include the temperature, relative humidity, and velocity of the air, the relative geometrical arrangement of the drying substance and the air stream, and the presence in the dryer of heat-radiating and heat-conducting bodies.

In general, the drying of most solids may be divided into three distinct periods: a heating period, a constant rate of evaporation period, and a falling rate of evaporation period. As an illustration of these three periods the following is cited. If a moist piece of material is brought into contact with a warm air stream, the water on the surface begins to evaporate and the vapor diffuses through the surrounding air film; then it is carried away by the turbulence in the air film. The material soon approaches the wet-bulb temperature since the latent heat for evaporating the water is usually high relative to the sensible heat of the material. The material therefore acts as a wet-bulb thermometer, with the heat transferred from the warm air and the surroundings to the surface being quantitatively consumed in evaporating water from the surface. The period in which the material passes from its initial temperature to that of the wet-bulb temperature is called the heating period.

As the water on the surface is removed, additional water may flow to the surface from the interior of the material. This period under constant drying conditions is characterized by the constancy of evaporation rate and is called the constant-rate period. This rate of drying is constant until a definite moisture content is reached, after which the rate of drying steadily decreases. This fact indicates that during the constant-rate period liquid moisture is diffusing through the solid to the surface at a rate equal to that of the evaporation from the surface. As the moisture content of the layer diminishes a point is reached at which the power of the solid to deliver moisture to the surface becomes less than that of the air to remove the moisture by evaporation. This activity causes the plane of evaporation to move from the surface of the material into the interior of the solid.

Once the plane of evaporation starts moving into the interior of the solid, the rate of drying begins to diminish and the falling rate of drying starts. The rate of drying slows down because the water vapor, instead of being formed at the upper surface of the solid and being picked up by the moving air stream passing over the surface, is now being formed inside the material and has to diffuse through the solid before reaching the air stream, where it is removed. As drying now proceeds the plane of vaporization will continue to fall resulting in a very slow rate of drying at the end of the drying period.

Figure 1 represents a typical drying curve for a solid material. A - B represents the heating period, B - C represents the constant-rate period, and C - D the falling-rate period.

If the material being dried adhers to the drying trays, as it sometimes will happen with some fruits, a drying curve as represented in Figure 2 will be obtained. Drying proceeds normally at first while the surface moisture and internal reservoirs are being exhausted. When most of the cavities are emptied, the only moisture supplied to the surface will be that held in the capillaries. The liquid will then begin to rise in the capillaries, and as the bottom of the fruit adheres firmly to the tray, air is unable to enter the bottom openings. As the liquid rises, a vacuum is created in the capillaries and liquid will then be prevented from rising to the surface. With the supply of water diminished, the rate of drying will decrease immediately. Some moisture will vaporize in the capillaries

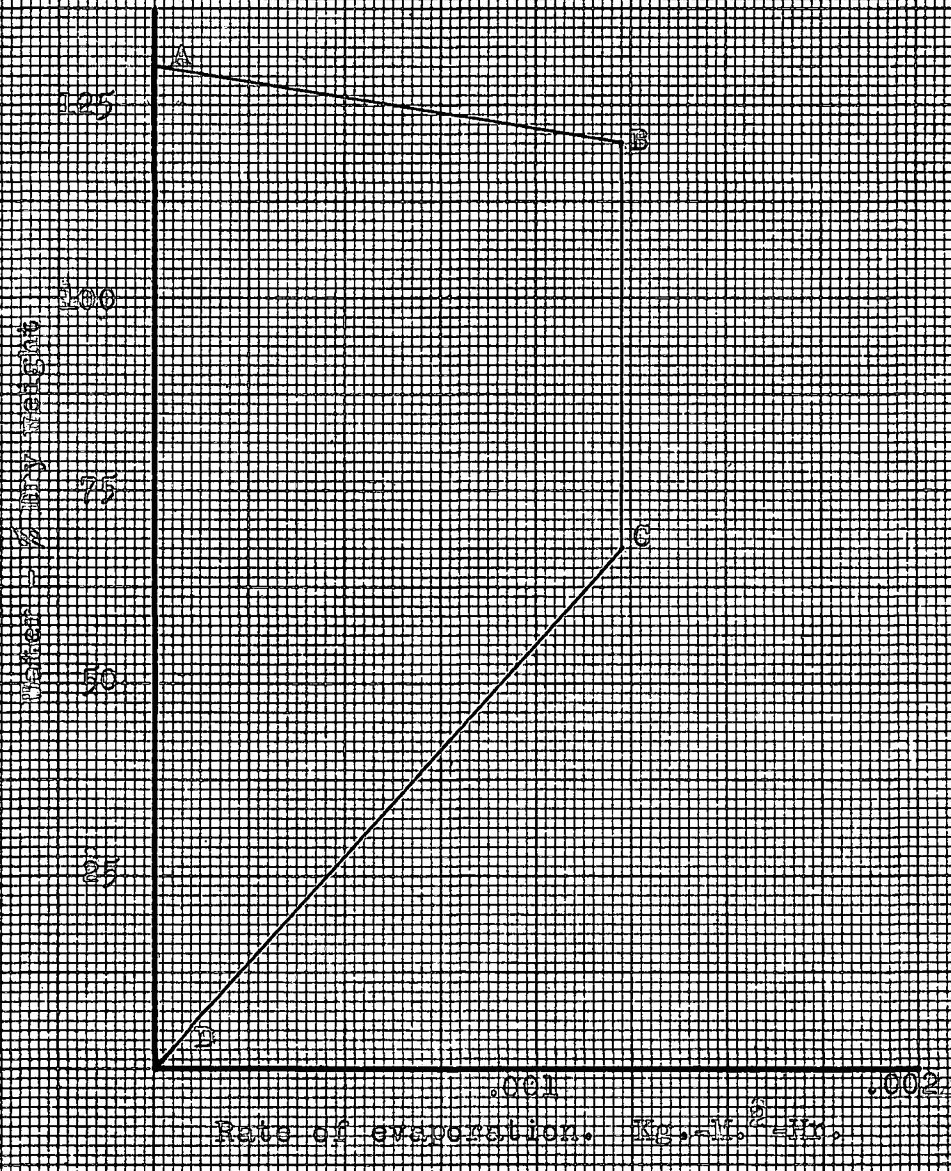


Fig. 1. Drying curve for free solid.
(after Stacey)

and the rate will never reach zero. When drying has reached a certain point, the material being dried which has been shrinking, will pull away from the bottom of the tray, and air will enter the capillaries. The drying rate will rise immediately with a new supply of moisture at the surface, and drying will proceed normally.

Having observed the mechanism of drying the use of the dehydrator should be discussed. The type of dryer which has largely superseded all other forms of large-scale commercial drying of fruit and vegetables is the forced draft tunnel dryer or air-blast dehydrator. Earlier forms are kiln driers (still extensively used for apples), stack dryers, in which the material enters the dryer on trays at the top of a vertical shaft and is removed at the bottom, and tunnel dryers (such as the Oregon tunnel). Both of the latter types make use of the natural draft caused by the tendency of heated air to rise, the source of heat being at the lowest point of the system.

Vacuum dryers, in which the drying is carried out under reduced pressure, have been constructed for the dehydration of products sensitive to heat. But such equipment is expensive, and not in general use for fruits and vegetables.

Although forced draft and recirculation are used in most tunnel dehydrators the methods of heating and conducting air flow through the plants vary considerably with the dehydration units sold by different manufacturers.

The air to be passed over the drying fruit or vegetable is heated by direct heat, direct radiation or indirect radiation. By direct heat is meant the addition of heat units to the air used in drying without the intervention of furnace walls or flues. This practice can be done only in instances in which there are no combustion products that might damage the product. This heating system is particularly well adapted to the use of natural gas as fuel.

Direct radiation as used in the drying industry refers to the absorption by air of heat from burning fuel by direct radiation through the furnace walls, flues, or radiators. This system offers the advantages of being clean and permitting the use of any kind of fuel.

Indirect radiation is the generation of heat at a distant point and its transportation to a point at which air is to be heated by means of steam or hot water radiators.

The counter current and combination air movement systems are in most common use today, but the parallel current and constant temperature air movement systems also have been used to some extent in the dehydration of fruits and vegetables.

When the counter current system is used the air and product move in opposite directions through the drying tunnel. The fruit or vegetable enters at the cool end of the tunnel and finishes at the hot end of the tunnel.

In the combination system of air movement the air-flow is so arranged that the highest temperature is at the center of the drying tunnel. The tunnel may be straight with the air flowing toward the ends from the center, or it may be "U" shaped with the air flowing from the bend of the "U" toward each end. In either case the material enters at a lower temperature and moves toward the hotter air at the center, reaching it after about half of the drying period is over. Then the fruit or vegetable moves past the center and finishes drying at the second cool end of the tunnel. Although this system is used rather extensively it is more difficult to control than the more simple counter current system. If the temperature at the center is allowed to exceed the critical temperature, the temperature at which the product may suffer heat damage, overdrying, injury, and loss in yield may result unless all pieces dry at the same rate.

When the parallel-current system of air-flow is used the fruit enters at the hot end of the tunnel and moves in the same direction as the air flow. This system seems satisfactory from the standpoint of critical temperature but it is unsatisfactory from the standpoint of evaporation of water because of the sugar and gum content of the fruit. Water is easiest to evaporate at first and hardest at the end. A high initial temperature often causes bleeding or exudation of juices from the fruit with a resulting loss in yield. Cruess (1938) states, however, that this system is suitable for the dehydration of vegetables.

The constant temperature or cabinet system is rarely used and is of value only when small plants are drying a variety of products, such as vegetables, and it is desirable to keep them in separate drying cabinets.

In most dehydrators the air is drawn from the heating chamber and forced through the drying chamber under a pressure. This procedure gives more positive distribution and temperature control than if air is drawn through the drying chamber. A good air-flow is necessary and usually should not be less than 500 lineal feet per minute. Christie (1921) has classified air velocities between trays in tunnel dehydrators as follows: below 400 feet per minute - poor, 400 to 600 feet per minute - good, 600 to 800 feet per minute - excellent, and 800 to 1,000 feet per minute - exceptional. In order to obtain these air flows various types of fans have been tried. It is now held that the multivane fan and the propeller type fan are best. The latter type is much cheaper than the former.

The effectiveness of a dehydrator fan depends to a considerable extent on the cause of air movement. When air is forced through narrow channels back and forth across the tunnel as is done in some cases it is necessary to use fans capable of overcoming the static pressure. In some instances two fans, placed laterally or at the end of the tunnel, are used.

The volume of air has no effect on the quality of the product, but uniformity of distribution is important in obtaining uniform drying. The rate of air-flow, however, is very important from the standpoint of dehydrator capacity and efficiency. More rapid air-flow induces faster drying, and hence greater capacity and less cost per ton. Therefore power, fuel, and labor operation are diminished. If the length of the drying tunnel is increased the velocity of the air-flow should also be increased correspondingly in order that the temperature drop and humidity increase will not be so great as to prevent drying at the cold end. The decrease in temperature is dependent on the relative volume of air, the product to be dried, and the rate of evaporation from the fruit. Dehydration tunnels should be from forty to fifty feet long (Wiegand, private communication).

It is characteristic of most operators to recirculate as much air as possible in order to obtain maximum fuel efficiency. On the other hand, recirculation is sometimes minimized during the rush season in order to reduce the drying time. This practice has often caused inexperienced operators to suffer great losses resulting from "case-hardening" and ultimate micro-biological and chemical deterioration.

In order to prevent case hardening the drying ability of the air must be limited to the ability of the tissues of the material to be dried to give up their moisture. The exudation of moisture from the product varies with the variety, maturity, season and the physical condition of the fruit. These factors should be taken into consideration by the operator of the dehydrator.

A dehydrator humidity in excess of twenty-five per cent at the hot end causes most fruits and vegetables to dry slowly, and tends to bring about more or less injury to color and flavor. Below fifteen per cent drying is a little faster and the fuel cost is noticeably reduced. If the product is placed in a warm air of high humidity which heats and expands the material but does little or no drying, the fruit or vegetable will burst, bleed, become sticky, and dry slowly. In most cases the humidity at the cold end of the tunnel should not exceed sixty to sixty-five per cent in order to permit drying to start immediately.

THE TUNNEL DEHYDRATOR

There are many forms of dehydrators in commercial use and many others have been designed but are not used commercially. In general, dryers may be placed into three classes, viz.: 1. natural draft dryers; 2. distillation dryers; and 3. forced-draft dryers.

Of these three classes the forced-draft dryer has found most universal use.

The forced-draft dryer may be subdivided into three types:

1. The continuous automatic type, in which the material is carried through the dryer by some sort of mechanical conveyance.

2. The compartment dryer, in which the material is stacked on fixed shelves and exposed to drying conditions.

3. The tunnel dryer, which is usually a double-tiered tunnel through the upper one of which the material is passed for drying, the lower tier contains the heating and air circulating units.

The forced-draft tunnel dehydrator is shown in Figures 3 and 4. It has proved to be the most efficient type of dryer in commercial use for the drying of fruits. It permits most rapid drying without injury, is the least costly dehydrator to build and to operate, and, according to Cruess (1938), permits of more uniform drying. It normally consists of a chamber which is longer than it is wide, and through which the product to be dried moves progressively on trays stacked on cars. The drying chamber or tunnel is supplied with a current of heated air which is introduced at one end and removed from the opposite end.

The furnace room may be located at one end of the tunnel, at the side, above or below the tunnel. A very convenient arrangement, and one which is most generally used, is that in which the furnace and heating systems are located in a tunnel below the drying tunnel with the fan also in this lower chamber as indicated in Figure 3.

The length of forced-draft tunnel dehydrators in commercial use varies from forty to seventy feet, though Wiegand (Private communication) advocates an optimum length of forty-five feet for efficiency. If the tunnel is longer than this, for example sixty feet long, very little if any drying occurs in the cars placed at the cool end until they have been worked up to ten to twenty feet towards the hot end. During this time marked deterioration of the fruit often occurs and it takes on a water-soaked appearance. In some cases severe drip or exudation of liquid from the fruit will take place.

Figure 3 shows the height of the tunnel to be five feet eleven inches. Commercial tunnel dehydrators are usually six to seven feet high. In all cases the height of the tunnel is determined by capacity, that is, by how many trays are to be stacked on the cars, and by efficiency of operation, since it is desired to stack the trays to within two inches of the roof of the tunnel.

It is important that the cars fit the tunnel walls closely to prevent air by-passing around the cars. To hold cars with trays of standard width (three feet) the tunnels are made three feet and three inches wide, inside measurement. The extra three inches is to allow one and one-half inch clearance on each side of the cars.

<u>Modes of heating air</u>. The air used in the tunnel dehydrator is usually heated by contact with steam pipes or with large flues heated by the products of combustion of natural gas, crude oil, wood, coal, or other fuel. It may also be heated by mixing with the products of combustion of a clean-burning fuel, such as stove distillate, kerosene, or gas.

The most common heating unit in use consists of a furnace room situated below the drying tunnel. This furnace is connected to a series of large sheet metal flues which are led along the tunnel beneath the drying chamber two or more times before joining the stack. In some cases the furnace and radiating pipes are replaced with a steam boiler and steam pipes, the latter placed immediately beneath the drying floor.

Fans. The heated air is either forced through the tunnel under positive pressure by means of a blower fan or is drawn through the tunnel by means of a suction fan.

Fans are of four types: disk, multivane, aeroplane-propeller, and paddle wheel. Cruess (1938) states that the multivane and the aeroplane-propeller types are the more efficient.

It is desirable that the forced-draft tunnel dehydrator be so constructed that any proportion of the air may be recirculated. For this purpose an inlet duct and an outlet duct are made, one at each end of the tunnel on the floor of the drying chamber. These ducts should be sufficiently large to allow free passage of air to and from the dehydrator. An outlet duct the full width of the tunnel and three feet across is often used. The proportion of recirculated air is also controlled by the adjustable apertures which allow the air to escape or be taken in from the outside. The ducts in the floor are rather for circulation than recirculation.

Tracks, cars, and trays. The material to be dried is usually spread on trays. Cruess (1938) claims that the most satisfactory tray for general use is the slat bottom tray measuring three feet by three feet. These trays are stacked on cars with sufficient space between the trays to allow the passage of the requisite amount of air. The cars are guided in the tunnel by tracks, and in some cases a track system is laid throughout the plant.

Capacity of tunnel. The holding capacity of a tunnel is usually based on the number of square feet of tray area multiplied by the load per square foot of trays, and the output per twenty-four hours depends on the drying time and is usually stated in tons of wet material. It may be considered that a tunnel is forty feet in length and holds twelve cars. Each car supports eighteen trays each measuring three feet square. The total tray area for that tunnel is then 12 (cars) x 18 (trays per car) x 3 x 3 (tray surface) square feet. These figures are equivalent to 1944 square feet. If one square foot of tray surface holds three pounds of fruit the capacity of the tunnel is 1944 x 3 = 5832 pounds. If the product is dried out in eight hours the tunnel can dehydrate a little less than three loads of 5832 pounds each in a twenty-four day. That is, its daily capacity for that particular kind of fruit is approximately eight tons.

Operation of tunnel dehydrator. The principles underlying the operation of a dehydrator have been considered. From these, the details of operation are easily understood. In the tunnel dehydrator operation would be as follows: when the first five or six cars of a twelve-car tunnel are loaded they are placed in the dehydrator, which has previously been heated. The fan is started. The temperature is set at the hot end at 165 degrees Fahrenheit.

As soon as the sixth or the seventh car is loaded, which should be in 30 to 45 minutes, the fan is slowed down, the doors opened and the car added at the cold end. This procedure is repeated until the tunnel is full. The cars are allowed to remain in the tunnel until the fruit in the first car is dried to the desired moisture content which is usually ascertained by feel.

Another car is then loaded and added to the cold end of the tunnel, displacing the first car out of the opposite end which is continued as the cars of fruit become dry.

Control. To produce a high-quality product under conditions of economical operation, it is necessary to have accurate control of the conditions of dehydration. This practice can only be done with control instruments and by keeping an accurate record of the air conditions during the operation of the dehydrator. Records can be used as a check on the plant operator and if at any time a poor-quality product is produced a complete set of records should reveal the reason.

The temperature of the air at the hot end of the dehydrator should be controlled. A recording dry-bulb thermometer should be placed at this end to accurately record the temperature of the air immediately before it meets the fruit. Temperatures above 170 degrees Fahrenheit at this point will cause scorching, though some fruits may escape injury until 175 degrees Fahrenheit is reached.

In the tunnel dehydrator a wet and dry bulb recording thermometer should be placed immediately before the outlet duct. A complete record at this point will largely explain heat losses and determine the amount of air to be released or recirculated. When the outlet air is at too low a humidity, outlet and inlet ducts should be closed. When the outlet air is at too high a humidity the outlet and inlet ducts should be opened to allow the escape of the humid air and its replacement by dryer air.

The anemometer is used for determining air velocity and is of value to the operator of a dehydrator. The maintenance of air velocities is important to rapid dehydration. Evenness of air flow and by-passing of air can be determined. To regulate air flow so that the drying air may pass over the fruit, baffles may be placed above the position of each car in the dehydrator if too much air is passing between the top of the cars and the ceiling, or baffles may be placed along the side walls of the tunnel if air is by-passing along the walls.

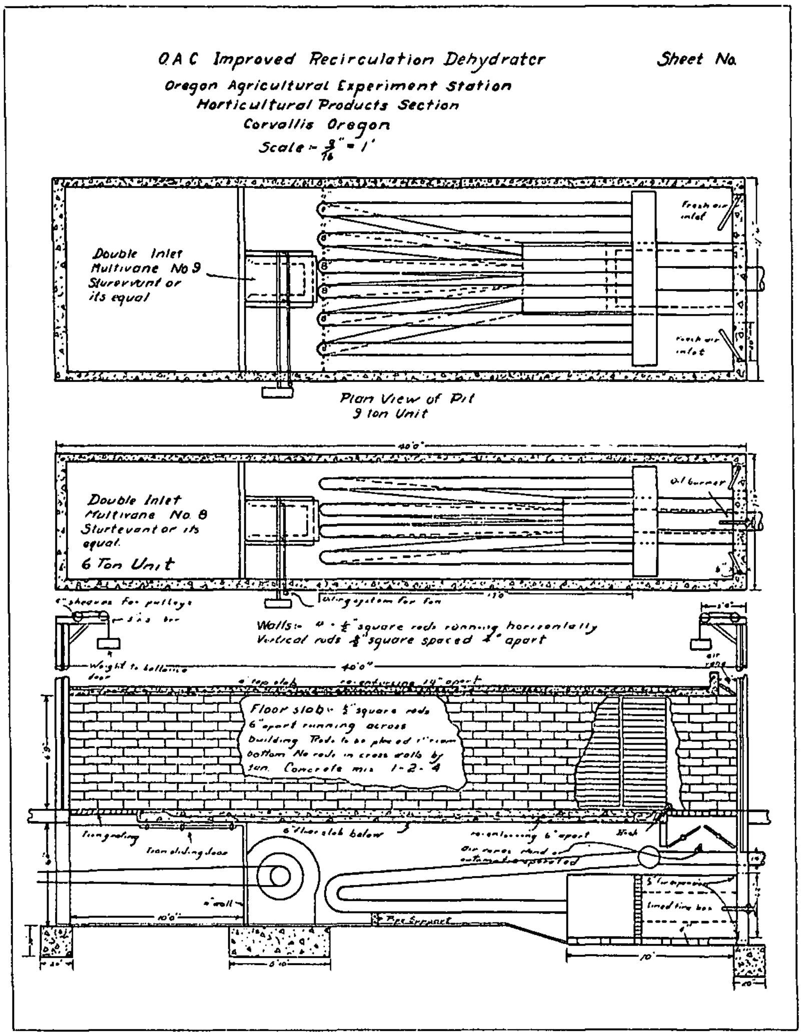
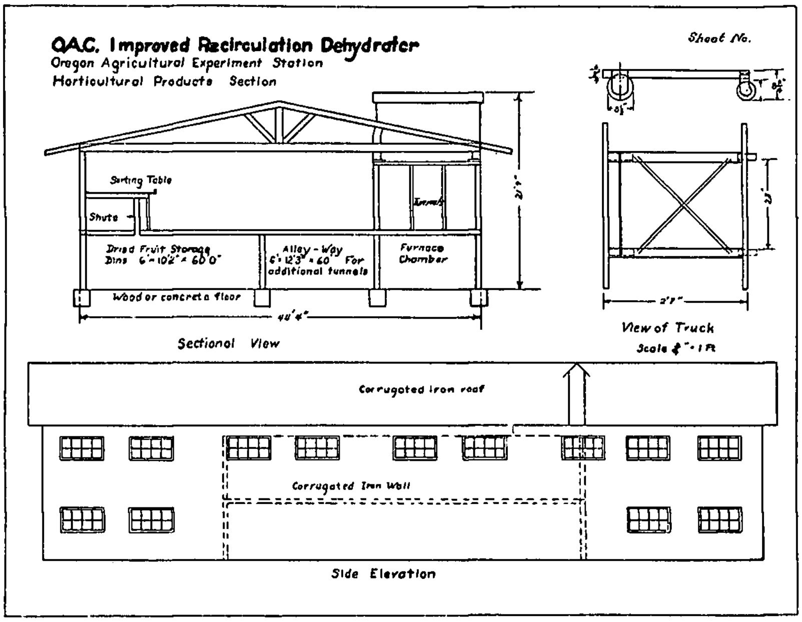


Figure 3. Plan and side elevation of two-tunnel (6-ton unit) and 3-tunnel (9-ton unit) recirculation dehydrater. (courtesy of E. H. Wiegand)



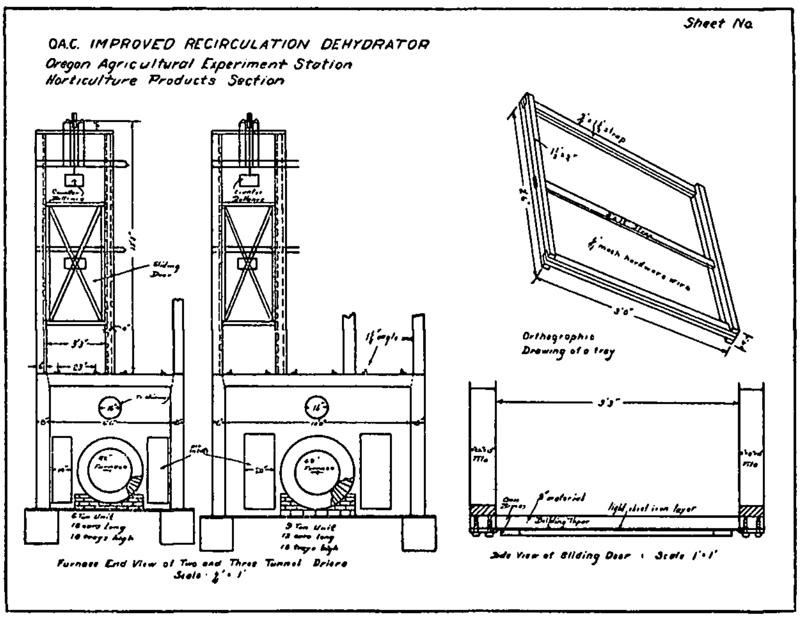


Figure 4. Building elevation and end elevation of recirculation dehydrater. (courtesy of E. H. Wiegand)

PRETREATMENT OPERATIONS

Sulfuring

Sulfur dioxide has been used for the treatment of foods since ancient times. Fruits are so treated in order to preserve their natural color, flavor, and, in part, to protect certain nutritive values. Sulfuring also prevents enzyme and microbiological deterioration, repels insects to some extent during storage, and facilitates drying by plasmolyzing the cells. Years of scientific investigations and practical experiments have failed to reveal another pretreatment agent equal to sulfur dioxide in preserving the desired qualities in cut dried fruits.

When sulfur is burned in air it combines with the oxygen of the air to form sulfur dioxide, a colorless gas. The white fumes commonly seen in sulfur houses are due to the fogging of water vapor about particles of sulfur trioxide simultaneously produced, but which represents a small portion of the sulfur burned. The formation of sulfur dioxide by burning sulfur in air may be stated by the following equation:

$$\underset{\text{(Sulfur)}}{S} + \underset{\text{(Oxygen)}}{O_2} = \underset{\text{(Sulfur dioxide)}}{SO_2}$$

When sulfur dioxide dissolves in water or fruit juice it forms sulfurous acid which is a weak acid. The equation for the reaction of sulfur dioxide with water to produce sulfurous acid is

$$\underset{\text{(Sulfur dioxide)}}{SO_2} + \underset{\text{(Water)}}{H_2O} = \underset{\text{(Sulfurous acid)}}{H_2SO_3}$$

Sulfurous acid is used as a preservative in numerous food products. This acid, and its salts (sulfites) are reducing substances (having oxygen removing power) and it is this property which is probably responsible for its action in preventing discoloration.

The control of sulfuring is of primary importance to the producer of quality dried fruits. The trade demands a light and uniformly colored product that will not deteriorate or darken during storage. For this reason the fruit must contain a sufficient quantity of sulfur dioxide when first dried.

When fruit once darkens during storage, subsequent exposures to sulfur dioxide will not change the appearance of the darkened fruit to that of the originally prepared fruit. Consequently it is often necessary to dispose of darkened fruit on a lower-quality basis and at a lower price. Love (1937) has emphasized the importance of the first sulfur treatment in regard to the retention of color in dried apricots.

To maintain the desired qualities in fruit it has been found necessary to incorporate in it an excess of sulfur dioxide to allow for losses occurring during handling and storage. The exact amount of sulfur dioxide needed to preserve the color and other qualities of dried fruits varies with the nature of the fruit and with storage conditions. For example, dried cut fruits may be relatively low in sulfur dioxide content and still retain the characteristic color of the fruit if properly and thoroughly dried. Cut fruits of high moisture content will darken during storage even though they contain a high initial sulfur dioxide content.

In South Africa and Australia systematic researches have been carried out on the sulfuring of fruits for drying in order to render the process less haphazard and to bring the finished product into line with the food regulations of the various countries to which the dried fruit is exported. These regulations are as follows:

TABLE I

Country	Parts per Million of Sulfur Dioxide
Great Britain	2000 (750 for raisins)
Canada	2500
Switzerland	2000
Germany, Austria, Hungary	1250
Czecho-Slovakia	1250 (raisins only)
France	1000
Japan	1000 (apricots) None allowed on other fruits
U.S.A.	2000

It is generally agreed that the variety, maturity, and general condition of the fruit are important factors in determining the absorption and retention of sulfur dioxide. Jewell (1927) stated that peaches and pears do not absorb sulfur dioxide as readily as apricots and for this reason are not as easily oversulfured. According to Culpepper and Moon (1937), peeling or slicing of pears enhances the absorption of sulfur dioxide. Quinn and associates (1929) indicated that fruit to be sulfured should be of "eating ripe" maturity. Nichols, Mark, and Bethel (1939) showed that color and sulfur dioxide retention by dried apricots varied with the locality in which the fruit was produced.

In Australia methods of sulfuring fruits, particularly apricots, have been developed and standardized as the result of the work of Lyon and others, and a report has been drawn up by a committee of experts the object of which was to recommend a procedure suitable for use in Australia and likely to produce a satisfactory product containing less than fourteen grains of sulfur dioxide per pound (2000 parts per million).

The chief recommendations in the report are given in the following points:

1. All fruits should be picked at "eating ripe" maturity and any over-ripe or unripe fruit should either

be discarded or sulfured separately. This action ensures uniform sulfuring, since firm fruit absorbs less sulfur than ripe fruit and generally gives an unsatisfactory product.

2. The sulfuring chamber should be of light material ("Mathoid" was recommended) and sufficiently air-tight to extinguish the sulfur fire when all vents are closed. In the case of movable hoods, precautions should be taken to prevent ingress of air at the base of the hood (as, for example, by packing with moist earth). A number of small units are recommended in preference to one large one so that fruit need not be held for any length of time after cutting and before sulfuring.

When one fire is used, a vent hole one inch in diameter should be provided in the roof of the chamber close to the wall farthest from the sulfuring fire or in the center of the roof when a fire is placed at each end of the chamber. A movable glass slide for inspection is also recommended.

3. Six to eight pounds of sulfur (dry) per ton of fresh fruit is recommended. The sulfur pit should be situated just outside at one or both ends of the chamber with a free entrance for fumes and a small inlet vent to admit the air necessary for combustion. The sulfur should burn steadily all the time the fruit is in the chamber and

slight fumes should be apparent at the vent hole. If all the sulfur is burnt before the expiration of the correct period, an excessive draught is indicated which should be reduced in subsequent operations until just a little sulfur is left.

4. Fruit should stand not more than one or two hours between cutting and sulfuring, and it should be stacked from the bottom upwards in the order in which it was cut. It has been shown that fruit when freshly cut absorbs sulfur most rapidly. The arrangement in stacking, therefore, tends to bring about uniformity, since the fruit with the driest cut surface comes in contact with the most dense sulfur fumes.

5. Four to six hours' exposure is recommended under average summer-day temperatures in Australia. On very hot days four hours is sufficient. It is not thought advisable that fruit should be left in the chamber over-night.

6. The characterties of correctly sulfured apricots are described as follows: The skin should be easy to de-tach, the color should be even, and there should be dis-tinct exudation of juice into the cups, although the fill-ing of the cups with juice is not a reliable indication of the completion of sulfuring.

The loss of sulfur dioxide from the fruit under different conditions of storage is illustrated by an experiment carried out by Nichols and Christie with dried apples initially containing one hundred forty-five parts per million of sulfur dioxide. Half of these were packed and stored at Berkeley, California, the other half were packed and sent to New York and back through the Panama Canal. After five months the former contained sixty-eight parts per million of sulfur dioxide and were in good condition, the latter contained only thirty-one parts per million. There was considerable darkening which was ascribed mainly to the loss of sulfur dioxide. Taking into consideration also the effect of sulfur in preserving vitamins, Nichols and Christie consider that it may ultimately be thought necessary to insist on a certain minimum of sulfur dioxide which the fruit must contain rather than a maximum which must not be exceeded.

There is no agreement concerning the desirability of sprinkling fruit with water or brine solution prior to sulfuring. Christie and Barnard (1925) believed that because the reaction $SO_2 + H_2O = H_2SO_3$ occurs during sulfuring it was desirable to sprinkle the fruit with water before sulfuring. Anderssen (1929) found that apricots moistened before sulfuring contained more sulfur dioxide than unmoistened apricots, but the final quality was about the same. According to Jewell (1927) the amount of moisture on the surface of the fruit influences absorption. Chace, Church, and Sorber (1930), on the other hand, could detect no differences in the absorption of SO_2 or in the appearance of fruit sprayed with water before sulfuring. Beekhuis (1936) states that the sprinkling of pears with water has been abandoned in many drying yards as it does not seem to answer any definite purpose. Lyon (1930), Nichols and Christie (1930), and Nichols (1933) state that sprinkling fruit prior to sulfuring has no beneficial effect. Storage of the fruit between cutting and sulfuring was considered undesirable by Beekhuis (1936) because it permitted drying of the fruit surfaces and he recommended that the period between cutting and sulfuring should be less than one and one-half hours.

Blanching in steam or hot water prior to sulfuring does not alter the sulfur dioxide absorption or retaining capacity of the fruit according to Nichols and Christie (1930) and Chace, Church, and Sorber (1933). Fruit blanched after sulfuring, however, retained fifty per cent more sulfur dioxide than unblanched fruit.

Morgan and Field (1929), and Morgan, Field and Nichols (1931), studied the effect of sulfuring of peaches, apricots, and prunes before drying on the retention of the antiscorbutic (C) vitamin. They found with apricots and peaches that if 450 - 500 or more parts of sulfur dioxide per million were retained, sulfuring protected vitamin C from destruction. With prunes this protection was greatest when the fruit had been dipped in boiling lye, owing to the fact that the lye treatment facilitated the penetration of the fruit tissues by the sulfur fumes.

Morgan (1935) found that vitamin B_1 is largely destroyed by sulfuring. She recommends that fruits rich in vitamins A and C be sulfured prior to dehydration to retain these desirable constituents and that fruits such as raisins which are rich in vitamin B_1 should not be sulfured but should be lye dipped and then dehydrated.

Blanching and Precooking

Most vegetables lose their color and flavor rapidly after drying unless they are blanched in steam, boiling water, or salt solution before drying. Blanching destroys the enzymes responsible for a great deal of the undesirable change occurring in dried vegetables, hastens the rate of drying in many cases, and arrests changes which tend to make the vegetables tough and difficult to cook. It also intensifies and fixes the color in some cases. Some vegetables however, such as tomatoes, onions, and peppers, are not improved by blanching. But the rule generally followed in dehydration of vegetables is "All vegetables must be blanched."

There are two general methods of blanching used in the dehydration industry, blanching in steam and blanching by immersion. Nichols and Gross (1921) said that blanching by immersion produces dehydrated products equally as attractive as those prepared by steam blanching, and blanching by immersion can be controlled more effectually than steam blanching.

Caldwell, Moon, and Culpepper (1938) list the following disadvantages of blanching by immersion:

1. There is a large loss of solids by solution in the immersion liquid.
2. Considerable quantities of liquid are absorbed, so that the time required for drying is increased.
3. The material becomes greatly softened during cooking, and much crumbling and breaking of slices occurs in spreading the blanched material on the drying trays.

The merits of steam blanching are claimed that there is less loss of soluble solids and less loss of vitamins than by the immersion process, and that less water is absorbed. Nichols and Gross (1921) say, on the other hand, "It is impossible to make definite statements of the exact number of minutes which each product should remain in any particular steam processing chamber in order to be properly blanched. The duration of exposure will depend upon the temperature of the product during exposure and the farther the temperature lies below 212 degrees Fahrenheit, the longer it will take to inactivate the enzymes and to reach the proper stage of cooking.

When we consider that the blanching is accomplished in a very few minutes, usually much less than ten minutes, it will be obvious that the deviation of a single minute from the proper time may produce an improperly blanched product. For these reasons, steam blanching is not as dependable as desired."

However, different vegetables react differently to these two methods of blanching. Cruess (1938) records that cabbage should be blanched in live steam about two minutes on screen trays. Nichols and Gross (1921) found that carrots gave the best dehydrated product when blanched in a boiling two per cent salt solution for two to four minutes; the same investigators found that potatoes responded best to steam blanching.

Okra should be sliced and blanched about two minutes in boiling water; string beans and peas should be blanched in live steam on screen trays three to ten minutes, depending upon their maturity.

Fruits are not generally blanched though some of them respond well to blanching either in steam or in boiling water. Cruess and Christie (1921a) report that in some plants prunes are blanched in steam before drying, steamed prunes drying slightly more rapidly than dipped prunes. They also reported that dehydrated steamed prunes were redder in color and more translucent than dehydrated lye-dipped prunes. With ample steam supply, two to five minutes' exposure to steam was found sufficient, but in instances where the steam supply was inadequate, a longer period of treatment was required. Prolonged steaming caused bursting of the fruit and sticking to the trays.

Certain varieties of grapes such as Tokay and Emperors respond satisfactorily to steaming. Plants in which only Tokay grapes are dried can use steaming to advantage.

Dipping

The purpose of dipping is to remove the dust and waxy bloom and to render the skin more permeable thus hastening the drying process. Ideal dipping "checks" the entire skin with many short, shallow cracks. Dipping that is severe enough to produce long, deep cracks is likely to peel some fruits. This treatment results in loss of juice and yield, sticky fruit, and sticky, troublesome trays. The more advanced the maturity of the fruit, the more severe is the dip required to check the skin. For this reason it is important that all the fruit handled be as uniform in maturity as possible.

Some plants have discontinued the practice of lye dipping their fruits because it is claimed that a "checked" skin detracts from the appearance of the fruit.

The fruits that are more commonly dipped prior to dehydration are prunes and grapes. According to Christie and Nichols (1929) lye dipping of prunes is not as essential in dehydration as in sun drying, though it is customary and desirable. It should be followed by rinsing in clear water, preferably with sprays. Over-dipping should be avoided for it causes prunes to bleed or drip, and stick to the trays.

According to Cruess (1938) grapes should be dipped in lye or sodium carbonate solution before dehydrating. Muscat and wine grapes which possess tough skins require a relatively strong solution (two to three per cent sodium hydroxide), while Sultanina (Thompson Seedless) and Tokay are tender-skinned and a dilute lye solution (one-fourth to one-half per cent sodium hydroxide) checks the skins satisfactorily. The length of immersion in the lye solution is from three to six seconds and the grapes are rinsed in water immediately after dipping.

Forest in 1929 took out a patent for improving the appearance of dried grapes by dipping the fresh fruit in a cold solution of sodium carbonate on the surface of which is a thin layer of oil expressed from the seeds of the grapes themselves.

According to Cruess (1938) cherries should be dipped in dilute boiling lye solution (one-fourth to one-half per cent) and rinsed in water before dehydration. Cruess and Christie (1921) said that dipping for 5 to 20 seconds in a boiling two per cent sodium carbonate solution, followed by rinsing in water, checked the skins of Royal Anne and Black Tartarian cherries more satisfactorily than did dilute lye solutions. These authors said that the lye tended to peel the more tender fruit, although good results were obtained commercially by dipping cull cherries for ten to thirty seconds in a boiling solution containing one per cent of Canner's alkali, a mixture of lye and carbonate. Dipping reduced the drying time approximately one half.

DEHYDRATION OF VARIOUS FRUITS

Since each fruit requires special treatment, it is best to consider each of the more important ones separately.

Apples

Apples for drying should be in firm condition, ripe but not over-ripe, and should give a clean, white product. The fruit is peeled, cored, and trimmed mechanically as in canning and may be cut into slices, rings, or dices. To prevent browning it may be given a preliminary sulfuring before slicing in an apparatus of the conveyor type, or the slices may be covered with a two per cent brine as in canning although Culpepper and Caldwell (1927) have shown that this procedure imparts a grayish color to the dried product with some varieties.

Cruess states that complete sulfuring of apples in the unsliced peeled condition requires forty-five to ninety minutes as against twenty to thirty minutes after slicing or fifteen minutes if the slices are previously dipped in a three to five per cent salt solution. Nichols and Christie (1930a) state that sliced apples should never receive less than one hour's sulfuring - preferably two hours - and that there is no danger of the presence of excess of sulfur dioxide in the finished product. In fact, the difficulty is rather to cause the fruit to take up sufficient for preservation (not less than 200 parts per million).

Cruess states that apples lend themselves well to the parallel system of air circulation by which it is possible to dry them in two to three hours. The temperatures in use are 180 degrees Fahrenheit for the lower-most trays in stack driers, and 140 to 175 degrees Fahrenheit for air-blast driers. Nichols and Christie (1930a) recommended the counter current system using as the maximum temperature 160 to 165 degrees Fahrenheit. These authors state that for rapid drying the relative humidity should not exceed eighteen to twenty per cent at the hot end.

Apricots

According to Morris (1933) dried apricots have the finest flavor when prepared from fully ripe fruit, but such fruit is difficult to handle and may lose its shape in drying. Under-ripe fruit on the other hand yields a shriveled tough product of poor flavor. The fruit should be ripe enough for eating, and slightly riper than is required for canning.

Apricots are not peeled but are cut in halves around the suture by hand and the stones removed. The halves are arranged cups upward on trays and sulfured for

for two to four hours. The finished product should contain about 1500 parts per million of sulfur dioxide.

In dehydrating, Cruess (1938) recommends that the temperature at the end of dehydration should not exceed 160 degrees Fahrenheit, and states that 150 degrees Fahrenheit or below gives the best results. According to Nichols and Christie (1930a) the most desirable humidities at the hot end of the tunnel should be approximately twenty-five per cent. The air velocity should be the maximum consistent with efficiency - not less than 500 and not more than 800 feet per minute.

Bananas

Experiments in the Fruit Products Laboratory of the University of California at Berkeley demonstrated that a dried product of attractive appearance and pleasing flavor could be made from bananas in the following manner. The ripe fruit was peeled and sliced longitudinally in halves or in strips about a quarter of an inch in thickness. It was then spread on trays, sulfured for twenty to thirty minutes, and dehydrated. A temperature of 200 degrees Fahrenheit was used while the fruit still contained a large amount of water, but 165 degrees should not be exceeded during the last stages of drying. Twenty per cent moisture in the finished product gave a very desirable texture.

The drying ratio of the peeled fruit was approximately 5:1, of the unpeeled fruit, 4.5:1.

Berries

Loganberries: Cruess and Christie (1921a) report that firm, ripe, freshly picked loganberries yield a dehydrated product of excellent flavor and color, with the individual berries equal in size to the original fresh fruit. Over-ripe and bruised berries lost considerable juice by dripping and tended to form "slabs." They recommended the parallel current system using an intial temperature of 200 degrees Fahrenheit and a final temperature of 160 degrees Fahrenheit. The initial humidity is six per cent relative humidity and the humidity of the outlet end thirty per cent relative humidity. Under these conditions and with an air velocity of 975 feet per minute drying was completed in seven to eight hours.

Raspberries: Raspberries are dehydrated without preliminary treatment. A dehydrated product of excellent color and flavor is produced by starting drying at 189 degrees Fahrenheit and ten per cent relative humidity and finishing at 160 degrees Fahrenheit. Using air at a velocity of 975 feet per minute, drying is completed in four and a half hours.

Cherries

Cherries are washed, the stones either removed by machinery or not as desired, trayed, steam-processed, and dried. This fruit may be lye-dipped to crack the skins and, if of the white variety, sulfured for a short time. Cruess gives the maximum temperature at the end of the drying period as 170 degrees Fahrenheit and the humidity ten to twenty-five per cent relative humidity. The cherries will then dry in eight to twelve hours.

Dates

According to Cruess dates to be packed as dry dates are placed in the dehydrator directly from the tree and dried at about 110 degrees Fahrenheit to the desired moisture content. During drying they lose their astringency and become semi-translucent.

Figs

Whole white figs, which have been allowed to ripen, to partially dry on the trees, and to drop to the ground before gathering, can be dehydrated in the whole state in nine to twelve hours at 165 degrees Fahrenheit. If the fruit is cut in half, drying is much more rapid.

Grapes

Cruess (1938) states that grapes in the dehydrating process respond well to the parallel current system with an initial temperature of 200 degrees Fahrenheit and a finishing temperature of 160 to 165 degrees Fahrenheit. Dipped grapes may also be dried in twenty or thirty hours by the counter-current system with a finishing temperature of 165 degrees Fahrenheit. After drying they may if necessary be stemmed by machinery and seeded.

Nichols and Christie (1930b) state that a moderate humidity not exceeding twenty-five per cent at a finishing temperature of 165 degrees Fahrenheit is the most desirable for the dehydration of dipped unsulfured seedless grapes because it gives rapid efficient dehydration and a product most closely resembling normal, sun-dried, soda dipped raisins of good commercial quality.

Dehydrated white grapes such as Muscat and Thompson Seedless varieties are inclined to be more sticky on the surface than the sun-dried raisins and are usually lighter in color. So-called "golden bleach Thompson Seedless" raisins are now produced in considerable quantity by lye dipping, sulfuring for about three hours, and dehydrating. The grapes must be thoroughly ripe in order to produce raisins of satisfactory color and texture.

Peaches

Peaches for drying should preferably be of the freestone type, of large size, and high sugar content. The fruit should be firm but ripe, fully colored, and free from soft spots. The fruit is peeled by means of lye. It is halved, stoned, and sulfured on trays with the cups upwards for three hours according to Nichols and Christie (1930a). The finished product should contain 1,500 parts per million of sulfur dioxide according to Morris (1933). In artificial drying of peaches the temperature according to Cruess should not exceed 145 degrees Fahrenheit, owing to their tendency to caramelize. The relative humidity of the dryer should be about thirty per cent during the final stage to prevent case-hardening and the product should be firm, pliable, and of a golden color.

Pears

Beekhuis (1936) states that pears are in ideal condition for drying when the color has turned a deep yellow and when they are still fairly firm. A green hard pear will never make a satisfactory dried article while mushy fruit is difficult to handle in the cutting shed and is apt to lose its shape.

The ripe fruit is taken to the cutting shed where the pears are cut into halves. The calyx and stem are removed and all damaged or decayed parts cut out. It is very important to remove the calyx because of the spray residue it carries.

The peeled halves are sulfured to prevent discoloration. However there are wide variations in the length of the sulfuring period due to the fact that pears, like apples, do not readily absorb the sulfur fumes. Nichols and Christie (1930a) give six hours as the minimum sulfuring period when the sulfur is burned by natural draft. Nichols, Powers, Gross, and Noel (1925) recommend dipping in cold water or a weak saline solution, as for apples, to prevent browning between operations.

A maximum temperature of 150 degrees Fahrenheit at the end of the drying period is recommended.

<u>Prunes</u>

Prunes are one of the most important of the dried fruits. They are allowed to ripen on the trees until they fall to the ground either naturally or with slight shaking. Further treatment consists in washing with cold water and dipping in a weak, boiling solution of lye (average strength about five-tenths of one per cent) for about fifteen seconds, or until the skins become "checked" and the waxy bloom is removed. Some varieties require more careful treatment than others, and these respond best to a dip in hot water. In any case immersion must not be long enough either to cause the skin to come off or to cook the fruit appreciably. After this treatment the fruit is rinsed and spread on trays to dry without any sulfur treatment.

In dehydrating, the initial temperature must not be too high, as this will cause dripping. The temperatures recommended by Cruess (1938) are 110 to 130 degrees Fahrenheit at the start and 160 to 165 degrees at the finish with a relative humidity of at least twenty per cent to prevent case-hardening.

Christie (1921b) recommends entering the fresh fruit at the cooler end of the dehydrator at 120 to 140 degrees Fahrenheit, finishing at a temperature not exceeding 165 degrees Fahrenheit and a humidity not exceeding twenty-five per cent.

W. S. Richert (1937) states that after drying, the prunes are allowed to "sweat" in small bins for a few days to equalize the moisture content. Christie (1921b) recommends that the dried prunes should be stored in bins for at least two weeks before delivery to the packing house.

At the storing house the prunes are processed. The processing operation for this fruit is quite simple. After removal from storage it is washed lightly and then given a dip in boiling water or is steamed for a few minutes. The purposes of the treatment are to wash the fruit, make it more edible by softening it, and destroy any insects or microorganisms that may be present. The prunes are then packed.

Lewis recommends that Italian prunes be dried to a moisture content of approximately eighteen per cent. However, if the fruit is dried to a very low moisture content there is great danger of scorching.

Christie (1921b) states that prunes containing in excess of twenty-six per cent moisture will eventually mold. Prunes of such high moisture content will not withstand binning, grading, or processing without injury. Prunes should not be binned with a moisture content in excess of about twenty per cent.

Persimmons

In experiments carried out by Christie (1921a) excellent results were obtained by peeling and slicing the firm ripe fruit and drying it without further treatment. J. M. Arthur also states that the fruit should be dried when it is firm ripe as when it is soft ripe it is mushy to handle and it tends to stick to the trays. The fruit should then be steamed to prevent darkening of the color but not sulfured since sulfuring causes the fruit to retain its astringent taste, which otherwise disappears entirely during drying. The best product is that which is peeled and then sliced before drying.

DEHYDRATION OF VARIOUS VEGETABLES

Beans

Beans for dehydration should be of the stringless variety. The stems and tips are removed, the beans then washed in cold water, drained, and cut into predetermined sizes. They are then blanched in steam from three to five minutes and placed into the dehydrator.

Starting temperature, 110 degrees Fahrenheit.

Finishing temperature, 145 degrees Fahrenheit.

Beets

For dehydration Andrea (1920) recommends the use of young beets. All the root and three inches of the top on the beet should be left. Wash and blanch in boiling water until the skin can be slipped off easily. Dip in cold water to remove skins, trim, and slice into pieces one-eighth inch in thickness for dehydration.

Starting temperature, 110 degrees Fahrenheit.

Finishing temperature, 145 degrees Fahrenheit.

Brussels Sprouts

Brussels sprouts are washed in water, drained, cut in halves lengthwise, and placed on trays. They are blanched in steam for three minutes, and placed in the dehydrator.

Starting temperature, 110 degrees Fahrenheit.

Finishing temperature, 145 degrees Fahrenheit.

Cabbage

Nichols and Gross (1921) found that cabbage blanched by hot water and hot two per cent sodium chloride solution was more attractuve than steam blanched cabbage. Cruess (1938) recommends that cut cabbage be blanched about one minute in live steam claiming that this intensified the color. He states that a temperature of 145 degrees Fahrenheit should not be exceeded during drying, that the cabbage is dried until crisp and should be packed in moisture-proof containers.

Gore and Mangels (1921b) found that cabbage dried to 3 to 3.34 per cent moisture can be stored in air-tight containers at ordinary temperature for six months or more without deterioration in color or flavor.

Carrots

In experiments on the blanching of vegetables it was found that it is possible to produce more attractive dehydrated carrots by blanching by immersion in hot two per cent salt solution, hot one per cent baking soda solution, or in hot water, than by processing by steam.

Core and Mangels (1921b) found that carrots are stable to color and flavor changes when dried to 4.99 to 7.39 per cent moisture. These workers also found that carrots are fairly resistant to heat. Tsu (1940) found them to be more heat resistant than spinach and peas.

Since carrots will withstand relatively high temperatures, Cruess (1938) says that they may be dried rapidly and should be dried until hard and brittle.

Cauliflower

Cruess (1938) says that cauliflower gives a fairly satisfactory dehydrated product. It is prepared as it would be for cooking for the table, being broken or cut in smaller pieces. These pieces are blanched in steam or boiling water four to five minutes. The temperature of drying should not exceed 140 degrees Fahrenheit because of its tendency to darken.

Celery

Both the leaves and stalks of this vegetable may be dried and used for the flavoring of soups, stews, and various culinary products, or for the preparation of powdered celery or celery salt. Only tender stalks relatively free from "strings" should be used. The stalks are trimmed, washed, and sliced. Blanching renders the product more tender, two to three minutes in steam or boiling water being sufficient. Celery leaves may be placed on trays separate from the sliced stalks. They require no blanching. The drying temperature should not exceed 140 degrees Fahrenheit.

Corn

The sweetest dehydrated product will be obtained from corn in the "milk" stage. The ears are husked as for canning and the corn is blanched on the cob in steam or boiling water for from five to ten minutes. It is silked as for canning, cut from the cob, spread on screen trays, and dehydrated to a low moisture content (six per cent). Cruess (1938) states that corn dried very rapidly will withstand a finishing temperature of 150 degrees Fahrenheit.

Garlic

Garlic powder is made by grinding dehydrated garlic. When mixed with cornstarch it is a product of considerable merit. The outer paperlike coating of the "buttons" is removed mechanically. The buttons are dehydrated without blanching, finely ground by hammer mill, and may be mixed with starch or flour. The powder retains its flavor indefinitely and is excellent for flavoring many foods such as gravies, stews, and spaghetti.

Onions

Onions should be trimmed, peeled by hand, and cut in very thin pieces because of the tendency of thick pieces to case-harden, to dry very slowly, and to darken.

Blanching is undesirable because it causes the onions to stick to the trays and does not improve their appearanc. Immersion of the sliced onions in cold five per cent salt solution for three to five minutes before drying reduces their tendency to darken during drying and later in storage.

A temperature of 140 degrees Fahrenheit should not be exceeded during dehydration, because of darkening of the color and loss of flavor at higher temperatures. The drying ratio is from 10:1 to 15:1.

Parsnips

This vegetable is one that should not be used if old as it develops a woody fibrous center. The parsnips are washed, scraped, cut into slices one-eighth inch thick, and placed on trays. They are blanched in steam for three minutes, removed, and placed in the dehydrator. Andred (1920) gives the starting temperature as 110 degrees Fahrenheit and the finishing temperature as 140 degrees Fahrenheit.

Peas

Peas for dehydration must be even less mature than for canning, because of the tendency of starchy peas to become tough-skinned and mealy during drying. The wrinkled varieties high in sugar content are much to be preferred to the starchy smooth-skinned varieties.

The peas are blanched in boiling water or live steam, as for canning, for two to five minutes depending on maturity and spread on trays directly from the blancher in a layer about three-fourths of an inch deep. The finishing temperature should not exceed 145 degrees since high temperatures cause browning and loss of flavor. The center of the pea dries slowly, therefore peas should be dried until a crisp and firm product is obtained.

Potatoes - White Potato

H. W. Banks (1921) states that potatoes dried by hot air must be so treated as to inactivate the oxidase which causes blackening on exposure to the air. This author reccommends immersing the peeled and sliced potatoes in boiling water for two to three minutes. The product being then dehydrated at 125 degrees Fahrenheit which temperature is gradually increased to 145 to 150 degrees Fahrenheit.

Nichols and Gross (1921) state that for potatoes a two minute treatment in steam prior to drying produces a product of a white and pleasing appearance. Andrea (1920) recommends a blanch of three minutes in steam followed by immersion in salted tepid water, the product being then dried at an initial temperature of 120 degrees Fahrenheit with finishing at 160 degrees Fahrenheit. Gore and Rutledge found that the temperature of dehydration which seems most desirable for potatoes, based on the results of their experiments on this vegetable and upon empirical observations, was 158 to 167 degrees Fahrenheit. Between these temperatures no visible gelatinization of the starch is evident. Dehydration is accomplished in five hours and the product on soaking in water for two and one-half hours is restored to 77 per cent of its original weight.

Potatoes - Sweet Potato

The sweet potato is the most heat resistant of the vegetables commonly used for dehydration. However, it is susceptible to discoloration. Magoon and Culpepper found that some degree of discoloration upon exposure to air occurred in all varieties studied by them but that it was most pronounced in deeply pigmented varieties. These workers observed that the discoloration at the surfaces of the slices appeared rather promptly after the material was placed in the drier, extending into the material along the vascular bundles and spreading and deepening in hue as the drying advanced. While this darkening largely disappeared in the process of soaking and cooking the material, it made the dry product so unattractive in appearance that it was necessary to find a method which would effectively prevent darkening despite the presence of optimum conditions for its occurrence.

In a series of experiments Caldwell, Moon, and Culpepper found that the most effective method of preserving the color was the use of two dips in two per cent citric acid solution. As rapidly as potatoes were washed and trimmed after peeling they were dropped into a tank of two per cent solution and allowed to remain three to five minutes. They were then lifted out and delivered to the operators who cut them into slices or strips, which were dropped as rapidly as prepared into a second tank of two per cent citric acid solution. Here they were agitated sufficiently to separate the pieces and bring all surfaces into contact with the solution, allowed to remain three to five minutes, then dropped out and spread directly upon the drying trays without rinsing.

Cruess (1938) states that sweet potatoes may be dried safely at 175 degrees Fahrenheit. The drying ratio is approximately 3.5:1, a higher yield of dried product than from any other common vegetable. This vegetable should be dried until brittle lest molding occur during storage.

Pumpkin

Pumpkin and squash are dehydrated for the preparation of "pumpkin flour," a finely ground, coarsely bolted mixture of the two vegetables. The pumpkins and squash are cut in halves and the seed and seed-cavity pulp removed. The unpeeled halves are then sliced or shredded and may be blanched or not blanched though the color is greatly improved if the slices are steamed on the trays until heated through.

Andrea (1920) recommends a starting temperature of 110 degrees Fahrenheit and a finishing temperature of 140 degrees Fahrenheit. The vegetables are dried until less than six per cent of moisture remains. The product is ground and bolted or screened to remove the coarse particles which can be reground.

Spinach

The stems of spinach are dried separately from the leaves as they usually require a longer time. If they were left on the leaves, the leaves would be dried to a powder stage when the stems were sufficiently dehydrated.

Spinach requires trimming, sorting, and very thorough washing before drying. Blanching consists in steaming on the trays two to three minutes. The washed leaves may be placed in a deep layer on the trays, provided air flow between trays is not seriously impeded.

The leaves dry very rapidly and a relatively high temperature of 175 degrees Fahrenheit can be used. The stems, because of their greater thickness, dry more slowly than the leaves. Spinach should be dried to less than six per cent moisture and packed at once in packages which resist penetration of moisture.

Tomatoes

Unpeeled tomatoes may be dried in sliced form but the quality is much improved by peeling before drying. Slices should be about one-fourth inch thick and no blanching is required.

Temperatures below 150 degrees Fahrenheit should be used as the slices darken at higher temperatures. They should be dried until the pieces show no moisture when pressed between the fingers or until the slices will break crisply on bending. The color is improved if the sliced tomatoes are sulfured in the fumes of burning sulfur for twenty to thirty minutes before drying.

Soup Mixtures

Various mixtures of vegetables have been prepared for making dehydrated vegetable soup. One mixture recommended by Caldwell (1918) is: potatoes 20 parts, turnip 20 parts, peas 20 parts, onions 6 parts, and 17 parts each of carrots and beans. All vegetables should be dried separately.

According to Andrea (1920) the vegetables are more attractive if cut in different shapes. This author suggests potatoes and turnips should be cubed, carrots cut in Julienne strips, and onions should be powdered.

In preparing soup mixtures it must be borne in mind that since the mixture must subsequently be soaked and cooked as a unit only such vegetables as absorb water and become cooked at approximately the same rate should be mixed. Peas and beans absorb water more slowly than the other vegetables unless they are cooked until almost ready for serving before they are dehydrated.

PACKAGING OF DEHYDRATED FOODS

No dehydrated product can be kept for long periods of time unless it is protected from absorbing moisture from the atmosphere. In the case of dehydrated fruits and vegetables the easiest way to prevent the absorption of moisture is to package and/or wrap the product in some material that is moisture-vapor-proof.

Waterproof materials must not be confused with moisture-vapor-proof materials as a packaging material may be waterproof without being moisture-vapor-proof. A waterproof material will not disintegrate in water and will also hold water whereas a moisture-vapor-proof material prevents moisture-vapor from passing through it, that is, it does not permit such air to diffuse through it.

In the packaging of dehydrated products there are certain problems that must be considered and these may be roughly classified as commercial, chemical, and physical.

The commercial problem involves manufacturing costs, strength and compactness, suitability for use with automatic handling equipment, sales, and consumer good will.

The chemical problem involves the minimization of enzymic and chemical changes by preventing access of outside air. The materials used in the manufacture of the container must result in a container that is odorless, tasteless, and non-toxic.

The physical problem involves the minimization of absorption of moisture from the atmosphere, which means packaging materials must be substantially moisture-vapor-proof.

Some of the more suitable materials are the following:

Cellophane. L. B. Steele (1930) states that cellophane was first introduced into the United States of America from France as a wrap for candy but that its basic characteristics fit it as a wrapping for all kinds of foodstuffs. The dried-fruit industry had turned to cellophane to a certain extent to provide a proper package for dates and figs. These fruits need to be openly displayed to permit their appetizing appearance as a sales aid and, at the same time, their inherent stickiness must be protected from dust and dirt. Other dried fruits - prunes, apricots, raisins - also are being successfully packaged in cellophane in some volume.

However, cellophane is not moisture-vapor-proof and cannot be used for packaging dehydrated vegetables since they absorb moisture from the air rapidly. There are now many specially treated moisture-proof cellophanes on the market and these are not only highly moisture-proof but are also grease-proof and completely transparent. A special form of moisture-proof film, the M.S.T. type of cellophane cellulose film, has the added advantage of being adaptable to heat-sealing.

Glassine and Wax Papers. Glassine paper is not wax paper. In the process of manufacture new spruce pulp is beaten much longer than if it were to be used for ordinary paper and the fibers become hydrated. In other words, water has been mechanically forced into the shortened cellulose fibers, making their texture gelatinous and grease-proof. To make this grease-proof material into glassine, the paper is polished in supercalenders, sealing in the water and giving the high transparency of real glassine paper.

Wax paper is made by applying melted wax to paper. The wax should be odorless, colorless, and of high melting point.

Glassine has many uses due to its excellent transparency, which is greater than any wax paper excepting waxed glassine. One of its advantages is the fact that it can be glued, as wax paper cannot, giving it a very wide use in bags.

Wax Paper. Ordinary wax paper is practically waterproof. Such papers are generally made from fully bleached strong fibrous pulp. A paper free from pinholes and imperfections is needed for wax paper because wax cannot be expected to fill more than the normal interstices between the fibers.

Paperboard Containers. Rectangular paperboard containers are often used in packaging dried foods. Their shape and size, being arbitrarily chosen, makes it an easy matter to pack the dried fruits and vegetables. Because of their shape they may be packed into shipping containers, storage rooms, and cars for transportation with practically no loss in space.

The most popular paperboard container is a rectangular Peters type lock-end carton. A package of that type for dehydrated fruits and vegetables should be lined and wrapped with a substantially moisture-vapor-proof material. These cartons may be had in many sizes and shapes, a common one used for retail trade being the 5x3x2 inch size.

METHODS EMPLOYED IN THE INVESTIGATION

Since the purpose of this study is to obtain and analyze the factors affecting quality, and as an aid to establish grades in dried fruits and vegetables, all available material relating to the drying, treatment, and packaging of dehydrated fruits and vegetables was assembled, analyzed, and studied. A comprehensive set of questionnaires was sent out to growers, dryers, packers, and research workers on dehydrated fruits and vegetables. This set of questionnaires is reproduced in the following pages; they cover the condition and treatment of the product before drying, conditions during drying, treatment of the product after drying, condition of the finished product, and buyer's preference.

Altogether one hundred ninety-eight sets of questionnaires were sent out. Throughout the study most of the organizations approached have given full cooperation and have supplied much information of a confidential nature which was essential for a thorough analysis of the situation.

The questions asked were so drawn that the answers would disclose definite information on the factors which should be taken as a basis for dividing various products into quality grades, the number of grades that should be given a particular product, and the limits (upper and lower) within which one grade ends and another begins. All the data obtained were tabulated, analyzed, and studied. The results were then correlated and compared with those obtained in the review of literature. On the basis of this comparison, tentative recommendations for the grading of the various commodities were drawn. These recommendations are given in Tables 1, 2 and 3.

RESULTS OF INVESTIGATION

According to the replies to questions on dehydrated fruits the average dryer, packer, and dealer is of the opinion that dehydrated fruits should be graded on color, flavor, texture, and on absence of defects as the four major criteria indicating quality. On the matter of absence of defects the consensus of opinion is that there should be a very limited and small tolerance for such defects as mold and decay, scorched and burnt fruit but for such defects as broken pieces, splits, slabs and for the presence of light scab a more liberal tolerance should be given. A tolerance of six to ten per cent is suggested for mechanical injury and two to four per cent for damage due to disease, insects, and bacteria.

The dry fruit industry is very emphatic on the need for standard size-grades for dehydrated fruits. The suggestion put forward is that it is desirable to have a few size grades rather than a multiple number. Four size grades are considered most desirable. For prunes the present system of grading fruits according to number per pound meets with approval. However, instead of dividing the prunes into ten or more size grades four are suggested. These size grades are fancy, or prunes counting 30 or less to the pound; choice, or prunes from 31 to 51 to the pound; standard, those counting 52 to 70 to the pound; and small, those counting 70 to 90 to the pound. Prunes counting more than 90 to the pound are held by some packers to be not desirable for human use.

The answers to the questionnaires indicated that the buying public judge quality of dried fruits largely on color and feel or pliability of the product. The color most desired from the point of view of buyer's preference is that it should be uniform and typical of the variety. The texture should be pliable and tender.

Uniformity of moisture content is also held to be a factor indicating quality, but, it is pointed out that buyers do not care about the actual percentage of moisture in a sample so long as it is uniform, and texture will serve as a good indication of moisture content. To prevent the growth of molds and other forms of deterioration in dried fruits however, it is held that dehydrated fruits should have a moisture content below that at which micro-organisms would grow. As an example, if eighteen per cent moisture is the safe limiting moisture content in prunes and if a packer puts out a prune of higher moisture content than this, then he should label his product as 'moist-pack' or some such designation to indicate to the buyer that it is liable to deteriorate and will not keep.

On the matter of introducing sugar content and vitamin content as grading factors the answers were an emphatic "no." Since sugar content varies with the environmental factors it would be unreasonable, as one packer puts it, "should an entire season's crop of dried fruit be judged sub-standard because the sugar content fell below some arbitrary percentage." With vitamin content the question resolves itself into one of finding a quick and accurate method of analysis. Since no satisfactory one has been found for testing the vitamins in dried products it will not be possible to enforce the ruling on vitamin content should one be established.

The replies to the questionnaires on dehydrated vegetables indicated that intrinsic characteristics such as flavor and odor are the most potent indications of quality. Since dehydrated vegetables are often sold in ground or in otherwise fragmentary form color is not held to be of major importance in grading though severely off-colored pieces are undesirable. On the matter of absence of defects it is the opinion that this factor is also not of high importance but that the presence of sand should be heavily penalized.

A part of the industry thinks, however, that standards should not be established for dehydrated vegetables. For their authority Chapter 4, Section 401, of the Federal Food, Drug and Cosmetic Act is quoted. This part of the Act reads as follows:

"Provided that no definition and standard of identity and no standard of quality should be established for fresh or dried vegetables or butter, except that definitions and standards of identity may be established for avocado, cantaloupe, citrus fruits and melons."

However, a large part of the industry holds the opinion that standards are desirable. This part holds that the tolerance for inorganic foreign material such as sand in dried vegetables should be very low, since, by proper preparation, foreign materials can be entirely removed except in crops such as spinach and even here the amount found in the product can be reduced to a minimum. For such crops the maximum tolerance should not be over 0.6 per cent.

The amount of defects should be limited by grade and definite standards should be set up. Three grades for dehydrated vegetables are suggested, namely, choice, standard, and substandard. It is evident that in establishing standards the tolerance for defects should be very low. The defects should be factors such as pieces of skin, insect punctures, off-colored pieces, and presence of tough and fibrous material. Since some of these factors are more important than others their tolerance should vary with their general effect on the product. It is suggested that a considerable quantity of only slightly off-colored pieces do not seriously affect the appearance of the product but a few badly discolored slices or pieces do. In view of this the relative degree of damage should be taken into consideration when establishing grades.

As with fruits the use of vitamin content or of mineral content as grading factors were not deemed practical. Maturity is a factor affecting the quality of dehydrated vegetables. Since over-maturity is indicated by the presence of stringy and fibrous material a limited tolerance should be placed on the presence of these.

All the data obtained were tabulated, analyzed and studied. Pertinent points were compared to and correlated with those obtained from the review of literature. With these as working bases the following general standards for dehydrated fruits and vegetables are drawn:

Tentative Grades for Dehydrated Fruits

Definition. Dehydrated fruits shall be the products prepared by evaporating the moisture from fresh, ripe, and sound fruit of the variety designated to such a point that molds, yeasts, and bacteria will not grow. Dehydrated fruits should retain the characteristic flavor of the fresh product, should have a bright, clean appearance, should retain substantially the whole nutritive value of the product before dehydration, and should have a texture which is not brittle or hard or over-tough, but is pliable and chewy in nature.

Dehydrated Fruits

Classes: Dehydrated fruits shall be divided into two classes as follows:

Class 1 . . . . Cut fruits

Class 2 . . . . Whole fruits

Cut Fruits

This class shall include all kinds of cut fruits such as sliced apples, halved peaches, quartered pears, and halved apricots. Cut fruits may be sulfured or not sulfured, and shall be divided into three subclasses as follows:

Subclass A .... Large cut fruit

Subclass B .... Medium size cut fruit

Subclass C .... Standard size cut fruit

Subclass D .... Small size cut fruit

Whole Fruits

This class shall include all kinds of whole fruits such as prunes, cherries, grapes, and figs. Whole fruits may be lye dipped, hot water dipped, or not dipped; they may be sulfured or not sulfured, and shall be divided into three subclasses as follows:

Subclass A .... Large whole fruit

Subclass B .... Medium size whole fruit

Subclass C .... Standard size whole fruit

Subclass D .... Small size whole fruit

Explanation of Terms

"Sound well-colored fruits" means practically whole pieces of fruit with a uniform color typical of the variety. Such pieces may be broken or cut on one side, but at least three-quarters of the piece shall be present.

"Color"

(a) If the color of the fruit is uniform and is typical of the variety, and bright, a credit of 28 -30 points may be allowed.

(b) If the pieces are somewhat deficient in color, a credit of 32 - 34 points may be allowed.

(c) If the pieces are fairly uniform in color but are dull, or if the color is variable, a credit of 28 -31 points may be allowed. Fruits that fall in this classification shall not be graded above grade C, or standard, regardless of the total score of the product.

"Flavor"

The quality of flavor of dried fruits shall be classified from the standpoint of palatability.

(a) If the fruit possesses the typical flavor of fully matured fruit, a credit of 23 - 25 points may be allowed.

(b) If the flavor is somewhat lacking in the highly desirable characteristics, a credit of 20 - 22 points may be allowed.

(c) If the fruit contains a fair fruit flavor, a credit of 14 - 19 points may be allowed.

"Texture"

(a) To receive a rating within the highest group, 32 - 35 points, for this factor, the fruit may be pliable and very tender.

(b) If the fruits are pliable but slightly less tender and ripe than those in group (a), a credit of 26 - 31 points may be given.

(c) If the fruits are pliable but the fibers are prominent but not hard, a credit of 21 - 25 points may bve given.

"Off-size" means pieces which are more than 20 per cent smaller or larger than the size stipulated in the grades.

"Mechanical injury" means any physical damage by bad bruises, splits, slabs, cracks, or tears.

"Biological injury" includes any injury caused by molds, bacteria, yeasts, or insects which materially affects the palatability or appearance of the fruit.

"Foreign material" includes sand, dirt, stems, seeds, or leaves, which materially affects the appearance or edible quality of the product.

For dried whole fruits the grades and the terms are similar except that in this case flavor is evaluated higher in its effect on quality than color.

"Moist fruit"

If the moisture content of the dehydrated fruit is above that at which deterioration may occur the term "Moist fruit" shall be inserted on the label after the grade designation.

The maximum limits of moisture content for the different fruits are:

Apples	24%
Apricots	24%
Cherries	20%
Figs	22%
Grapes	22%
Peaches	24%
Pears	24%
Prunes	22%

"Infested fruit"

The words "Infested fruit" shall be inserted in the designation of grades in dried fruits when live insects or live larvae of insects are found in that lot of dried fruit. Fruits thus labeled shall not be graded higher than grade D or substandard.

Tentative Grades for Dehydrated Vegetables

Definition. Dehydrated vegetables shall be the products prepared by evaporating the moisture from young, succulent, and sound vegetable of the variety designated to such a point that molds, yeasts, and bacteria will not grow. Dehydrated vegetables should retain the characteristic flavor of the fresh product, should have a bright, clean appearance, should retain substantially the whole nutritive value of the product before dehydration, and should have a moisture content of six per cent or lower.

Dehydrated Vegetables

Types. Dehydrated vegetables shall be divided into types as follows:

Type 1 .... Whole vegetable

Type 2 .... Sliced vegetable

Type 3 .... Shredded vegetable

Type 4 .... Ground vegetable

"Moist-pack." All dehydrated vegetables with a moisture content higher than six per cent shall be labeled "moist-pack" and all vegetables so labeled shall not be graded higher than substandard grade.

Explanation of Terms

"General appearance" includes such qualities as uniformity of size; characteristic color; and shape.

(a) If the general appearance is pleasing, that is, if the size and shape of the pieces are uniform and the color is typical of the variety, and bright, a credit of 25 to 30 points may be given.

(b) If the general appearance is satisfactory, that is, if the size and shape of the pieces are fairly uniform and the color uniform but are dull, or if the color is variable, a credit of 21 - 24 points may be given.

"Flavor." The quality of flavor of dried vegetables shall be classified from the standpoint of palatability and its resemblance to that of the fresh vegetable.

(a) If the vegetable possesses the typical flavor of young, succulent plants, a credit of 40 to 50 points may be given.

(b) If the vegetable contains a fair vegetable flavor, a credit of 35 - 39 points may be given.

"Odor"

(a) When the product is free from burnt, objectionable or off-odors of all kinds a credit of 16 - 20 points may be given.

(b) When the product is practically free from burned, objectionable, or off-odors or when there is a trace of smoke, a credit of 12 - 15 points may be given.

Table 1

PROPOSED FORM FOR GRADING DRIED FRUITS

GRADES FOR DRIED CUT-FRUITS

Grade	Minimum limits of:-						Maximum limits of:-			
	Sound well-colored pieces %	Intrinsic characteristics(100 pts.)					Off-size pieces %	Mechanical injury %	Biological injury %	Foreign material %
		General appearance Max. 25	Color 30	Flavor 20	Texture 25	Grade range				
A	92	23	28	18	23	92-100	4	6	2	0.6
B	88	19	25	15	19	78- 91	6	8	3	0.6
C	82	15	20	12	15	62- 77	10	10	4	0.6

D Substandard grade. All fruits failing to meet the above requirements shall be graded as substandard.

Table 2

PROPOSED FORM FOR GRADING DRIED FRUITS

GRADES FOR DRIED WHOLE FRUITS

Grade	Minimum limits of:-						Maximum limits of:-			
	Sound well-colored pieces %	Organoleptic characteristics (100 pts.)								
		General appearance Max. 25	Color 20	Flavor 30	Texture 25	Grade range	Off-size pieces %	Mechanical injury %	Biological injury %	Foreign material %
A	92	23	18	28	23	92-100	4	6	2	0.6
B	88	19	15	25	19	78- 92	6	8	3	0.6
C	82	15	12	20	15	62- 77	10	10	4	0.6

D Substandard grade. All fruits failing to meet the above requirements shall be graded as substandard dried fruits.

Table 3

REQUIREMENTS FOR DEHYDRATED VEGETABLES

Grade	Minimum limits of:- (total 100 pts.)			Maximum limits of:-			
	General Appearance	Flavor	Odor	Foreign inert inorganic matter	Defects: insect & bird punctures, pieces of skins & roots	Severely off-colored pieces	Stringy fibery matter
	Max. 30	50	20	%	%	%	%
A	25	40	16	0.4	4	2	2
C	21	35	12	0.6	6	4	4

D Substandard grade. All vegetables which do not meet the above requirements shall be graded as substandard.

DISCUSSION

The grading sheet for dried fruits and vegetables as given in this paper is different from that used for canned foods and other agricultural commodities for which grades and standards have been established. The reason for using this form is that it seems to be best from the point of view of taking into consideration all factors, intrinsic and extrinsic, that have a bearing on the determination of quality. And it is with quality that grades deal.

The factors to be taken into account in grading dried fruits and vegetables, according to the answers to the questionnaires sent out, are: Flavor, texture, size, appearance, freedom from damage or deterioration, freedom from disease, moisture content, absence of foreign material, dirt or insect infestation, and absence of scorch and caramelization. These can be grouped under five major factors, viz.: color, flavor, uniformity of size, texture, and absence of defects. The order of their importance in grading dried cut-fruits are indicated to be color, texture, flavor, absence of defects and uniformity of size. For whole fruits these factors assume the same order of importance as cut-fruits except that in this case flavor is deemed the most important and color ranks third in importance.

With vegetables flavor was deemed to be by far the most important indication of quality.

Taking all these factors into consideration it would seem that the plan followed for grading canned foods will adapt itself well to dried foods. However, the form used for canned food is essentially a score sheet assigning certain numerical values to different factors, the relative importance of each factor being expressed on a scale of one hundred. This plan is admirable for scoring such relative values as flavor, texture, and color; but, it is not critical enough for scoring defects for which exact tolerances may be allowed.

Standards for grades of dried prunes, which came into effect April 5, 1941, and the tentative standards for grades of dried apples are the only standards now available for dried fruits and vegetables. These standards follow the plan of defining the commodity, giving the styles or types in which these commodoties appear, the sizes, and the grades.

Under "Grades of dried prunes" or "Grades of dried apples" a description of what Grade A, B, and C should be, are given. In these standards for grades, intrinsic qualities such as flavor and texture are not taken into account. The factor of defects is taken as the main criterion for grading.

The grading sheet given in this paper attempts to follow a system whereby defects are segregated into their respective classes and limits are indicated for these defects in the various grades. It also takes into consideration intrinsic characteristics such as flavor, color, and texture. The system of grading intrinsic characteristics is copied from that followed in grading canned foods. Intrinsic and extrinsic characteristics are taken together and evaluated to give a more complete picture of the quality of the product. Moreover, the factors are all arranged in table form and exact tolerances and allowances are given for each factor. This system, it is hoped, will facilitate the work of grading.

Since it is with the marketing half of the problem of agriculture that the establishment of standards deals consumer's demand is most considered. With this problem in mind the questions asked in the questionnaires were so drawn that the answers would disclose definite information throwing light on the needs and wishes of consumers. The answers suggested that most consumers are rather particular about the appearance in dried fruits. This factor has prompted the insertion of "general appearance" and "color" in the grades and assigning values to them. In dried cut-fruit appearance counts a great deal since it indicates the amount of care taken during preparation. Accordingly, proper emphasis was given this factor which is represented in the grades by the designations "general appearance" and "color."

In dried whole fruits flavor is of major importance. Fruits must be allowed to reach full maturity to attain a maximum of sugar content and to attain the optimum in the sugar-acid ratio. Immature fruits produce a dried product which is tough and sour, and which has no place on the market. Therefore, by the insertion of flavor as a grading factor the use of ripe fruit for drying is encouraged.

The factor of "off-sige" pieces was put in in the dried fruit grades because it appears that packs of mixtures of irregular sizes will look uneven and lacing in uniformity and thus will projuce consumers when displayed for sale. The factor of mechanical injury is put in the system for the same reason.

Biological injury, as exemplified by the presence of mold and decay, is very objectionable and its tolerance is accordingly cut down.

Foreign material is undesirable in any food and it is hoped that they may be ruled off from the list of tolerances. However, the trade must be considered and since by the present commercial methods of handling foreign material is entirely excluded with difficulty a maximum tolerance of 0.6 per cent is allowed for such.

An interesting difference in grading dried fruits and vegetables exists in that the young, tender, most succulent, immature vegetables are usually graded highest, while the fully mature but not over-ripe fruits usually yield products which are most desirable. Since maturity in vegetables is indicated by the presence of stringy and fibrous material the presence of these are considered as an indication of off-quality, and limited tolerances are put on their presence.

The factor which counts most in dividing vegetables into quality grades is flavor since it alone will give a fair indication of the history of the product. Whether blanching has been adequate, and whether the temperature of dehydration was sufficient or over-reached are quality factors evident in flavor. It also gives a clue to the age and the handling of the dried product. Accordingly this factor is given pre-eminent consideration in grading.

SUMMARY

1. There are at present no official grades and standards established for dried fruits and vegetables, except that federal grades have been established for dried prunes and tentative grades have been drawn up for dried apples.
2. Answers to questionnaires sent out to individuals and concerns in the dried food industry show that the industry as a whole is in favor of having grades and standards established.
3. Standards for dried fruits and vegetables should have the aim in view of improving quality.
4. There should be strict limits for the presence of defects.
5. Tolerances should be so set that a more lenient penalty is exacted on minor defects, such as broken and trimmed pieces, splits, slabs, and slight discoloration. These defects do not detract from the food value of the product.
6. Tolerances should be so set that a strict censure is put on major defects, such as the presence of mold, scorched and burnt material, and the presence of foreign matter such as sand and dirt. These defects, if present, lower the food value of the product or are otherwise objectionable.

7. The existing trade practice of having multiple size grades impedes handling and is not practical.
8. There should be only a few size grades, with clear cut limits marking each grade.
9. The use of chemical composition as a measurement of quality is impractical.
10. Dried fruits may be conveniently divided into two classes according to their grading characteristics. These two classes are cut fruits and whole fruits.
11. The grading factors for cut fruits and whole fruits are broadly similar except that color is the most important grading factor for cut fruit while flavor is the most important characteristic for whole fruit.
12. The important factors considered in the grading of dried cut fruits according to their relative importance are: 1. color, 2. texture number, 3. flavor, 4. absence of defects and uniformity of size. For dried whole fruits these factors are: 1. flavor, 2. texture, 3. color, 4. absence of defects, and 5. uniformity of size.
13. Intrinsic characteristics such as flavor and odor are the most potent factors in determining quality. Of these two flavor is the more important.
14. Grades and score cards have been devised for grading dried fruits and vegetables. They were drawn in such

a way that every factor has a definite value or range for each grade, and, to make for maximum convenience and efficiency, all requirements are given in one page and in table form.

APPENDIX

Questionnaire on dried fruits.

1. What kind of dehydrater do you use?

2. In the labelling of packaged dried fruits, should the label bear full information of the product, as to its moisture content, culinary value, nutritive value; whether sweet or tart, its texture, digestive character, etc.? In your opinion do you think they warrant extra expenditure on labelling to increase their sale appeal?

3. In your opinion what is the most important factor affecting the quality of dried fruits?

FRUITS - TABLE I

Fruit	Annual output (tons)	Drying ratio X:1	Drying Season		Drying Tempt. °F.		Drying Humidity	
			From	To	Initial	Final	Inlet end	Outlet end
1. Apples								
2. Apricots								
3. Bananas								
4. Cherries								
5. Figs								
6. Grapes								
7. Loganberries								
8. Peaches								
9. Pears								
10. Prunes								
11. Raspberries								
12. Strawberries								
13. Others (please name)								

FRUITS - TABLE II

Fruit	Best Varieties for Drying	Preparation prior to drying					Sulfuring	
		Halving	Stoning	Peeling	Slicing	Blanching	Time	Tempt.
1. Apples								
2. Apricots								
3. Bananas								
4. Cherries								
5. Figs								
6. Grapes								
7. Loganberries								
8. Peaches								
9. Pears								
10. Prunes								
11. Raspberries								
12. Strawberries								
13. Others								

FRUITS - TABLE III

Fruit	Best condition for Drying (fresh state)											
	Maturity			Size			Color			Texture		
	Green	Firm	Ripe	Small	Medium	Large	Dark	Medium	Light	Hard	Firm	Soft
1. Apples												
2. Apricots												
3. Bananas												
4. Cherries												
5. Figs												
6. Grapes												
7. Loganberries												
8. Peaches												
9. Pears												
10. Prunes												
11. Raspberries												
12. Strawberries												
13. Others												

FRUITS - TABLE IV

Fruit	Desirable moisture content of Dried Product	Desirable condition Dry Product:					Size Grades	Desirable kind of Packaging
		Color	Size	Texture	Tolerance for:			
					Damage	Sand		
1. Apples								
2. Apricot								
3. Bananas								
4. Cherries								
5. Figs								
6. Grapes								
7. Loganberries								
8. Peaches								
9. Pears								
10. Prunes								
11. Raspberries								
12. Strawberries								
13. Others (please name)								

TABLE V - FRUITS

In grading dried fruits which factors are of most importance; color, uniformity of size, absence of defects, tenderness and texture, flavor? A sample score sheet is given below, please score the different fruits according to the importance of the different factors.

Fruit	Color	Uniformity of size	Absence of defects	Tenderness and Texture	Flavor	Total
Sample	20	10	15	35	20	100
1. Apples						
2. Apricots						
3. Bananas						
4. Cherries						
5. Figs						
6. Grapes						
7. Loganberries						
8. Peaches						
9. Pears						
10. Prunes						
11. Others (please name)						

FRUITS - TABLE VI

Fruit	Desirable Flavor of Dried Product			Should the following be used as grading factors:		Desirable size grades for the dried fruits:
	Sweet	Aromatic	Tart	Sugar content	Vitamin content	
1. Apples						
2. Apricots						
3. Bananas						
4. Cherries						
5. Figs						
6. Grapes						
7. Loganberries						
8. Peaches						
9. Pears						
10. Prunes						
11. Raspberries						
12. Strawberries						
13. Others (please name)						

Questionnaire on dehydrated vegetables.

1. What kind of dehydrater do you use?

2. Should mineral content or vitamin content be used as grading factors for dried vegetables?

   Mineral content. Yes _____. No _____.

   Vitamin content. Yes _____. No _____.

3. In sliced, shredded, or ground vegetables should there be size requirements for standard quality? What should those size requirements be?

   Sliced ____

   Shredded ____

   Ground ____

4. In dried vegetable soup mixtures should there be minimum requirements as to the proportions of different vegetables in the mixture? What should those proportions be?

5. In the labeling of packaged dried vegetables or soup stock, should the label bear full information of the product, as to its use, its moisture content, culinary value, nutritive value? In your opinion do they warrant extra expenditure on labeling to increase sales appeal?

6. In your opinion what is the most important factor in improving the quality of dried vegetables?

VEGETABLES - TABLE I

Vegetable	Annual output (tons)	Drying ratio X:1	Drying Season		Drying Temperature		Drying Humidity	
			From	To	Initial	Final	Inlet end	Outlet end
1. Beet								
2. Cabbage								
3. Carrot								
4. Cauliflower								
5. Garlic								
6. Green Beans								
7. Mint								
8. Onion								
9. Peas								
10. Potato								
11. Spinach								
12. Sweet Potato								
13. Others (please name)								

VEGETABLES - TABLE II

Vegetable	Best Varieties for Drying	Preparation for Drying:				Blanching			
		Slice	Cube	Shred	Ground	Water	Steam	Time (mins)	Temp
1. Beet									
2. Cabbage									
3. Carrot									
4. Cauliflower									
5. Garlic									
6. Green Beans									
7. Mint									
8. Onions									
9. Peas									
10. Potatoes									
11. Spinach									
12. Sweet Corn									
13. Sweet Potato									
14. Others (please name)									

VEGETABLES - TABLE III

Vegetable	Best Condition for Drying (fresh state)											
	Maturity			Texture			Size			Color		
	Green	Medium	Mature	Hard	Firm	Soft	Small	Medium	Large	Dark	Medium	Light
1. Beet												
2. Cabbage												
3. Carrot												
4. Cauliflower												
5. Garlic												
6. Green Beans												
7. Mint												
8. Onion												
9. Peas												
10. Potato												
11. Spinach												
12. Sweet Corn												
13. Sweet Potato												
14. Others (please name)												

VEGETABLES - TABLE IV

Vegetable	Desirable Moisture content in Dried Product	Desirable Condition of Dried Product					Desirable kind of Packaging
		Color	Consistency	Odor	Tolerance for defect		
					Sand %	D[illegible] %	
1. Beet							
2. Cabbage							
3. Carrot							
4. Cauliflower							
5. Garlic							
6. Green Beans							
7. Mint							
8. Onions							
9. Peas							
10. Potato							
11. Spinach							
12. Sweet Corn							
13. Others (please name)							

VEGETABLES - TABLE V

In grading dried vegetables what factors are of most importance. Color, flavor, odor, consistency and texture, or absence of defects? A sample score sheet is given below; please score for those vegetables you dehydrate.

Vegetable	Color	Flavor	Odor	Consistency and texture	Absence of defects	Total
Sample	20	20	15	20	25	100
1. Beet						
2. Cabbage						
3. Carrot						
4. Cauliflower						
5. Garlic						
6. Green Beans						
7. Mint						
8. Onion						
9. Peas						
10. Potato (Irish)						
11. Spinach						
12. Sweet potato						
13. Others						

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