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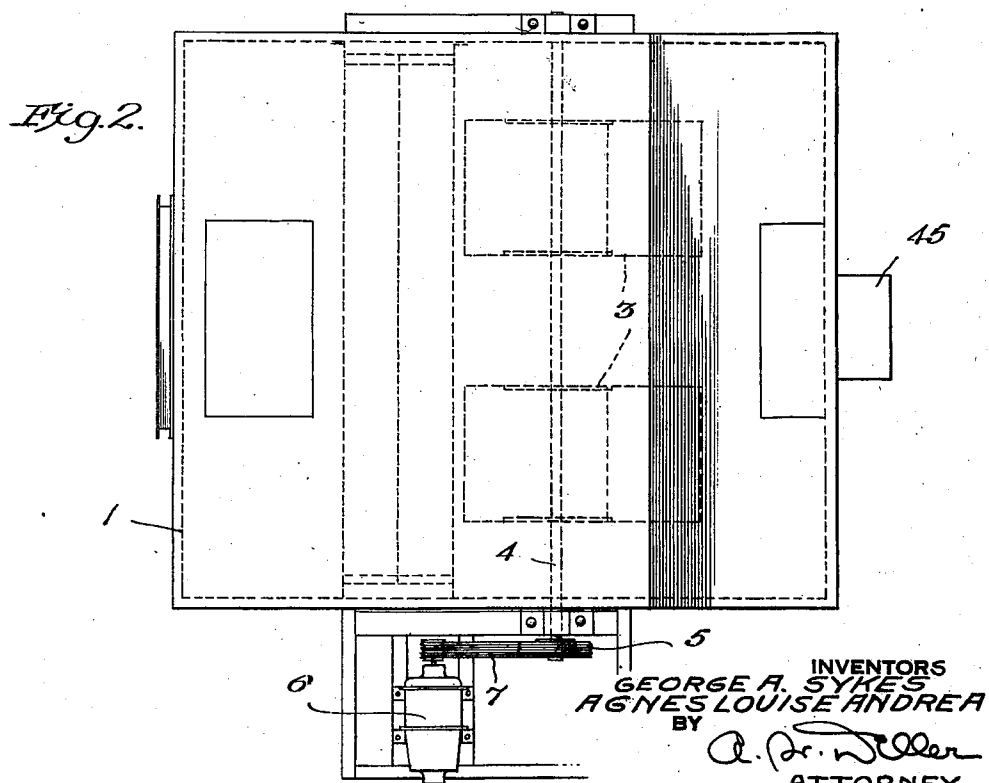
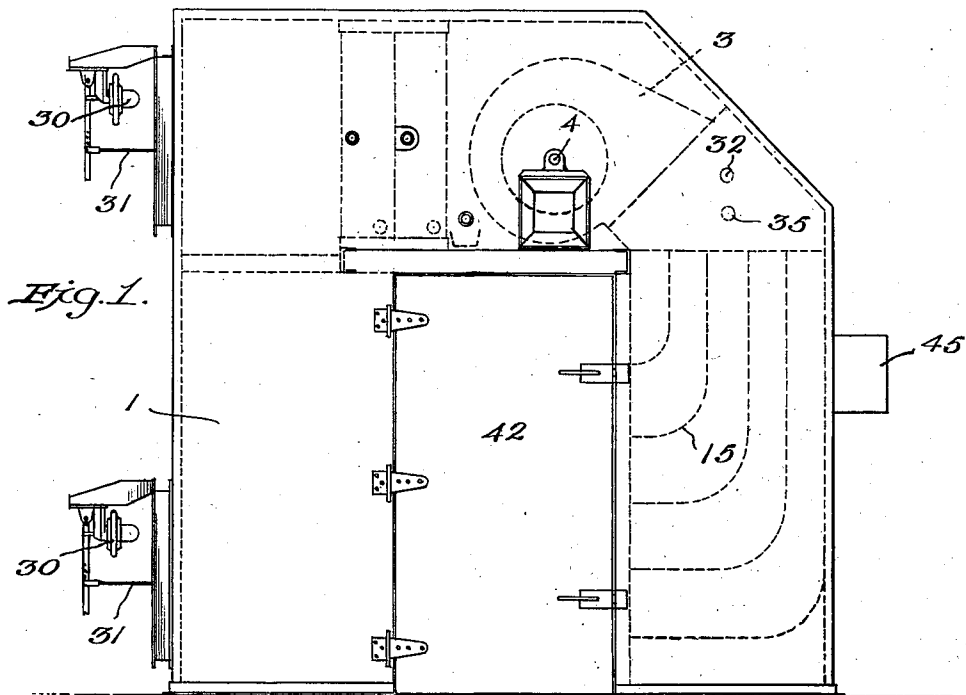
G. A. SYKES ET AL

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PROCESS FOR DEHYDRATING WATER-CONTAINING MATERIALS

Filed March 6, 1940

4 Sheets-Sheet 1



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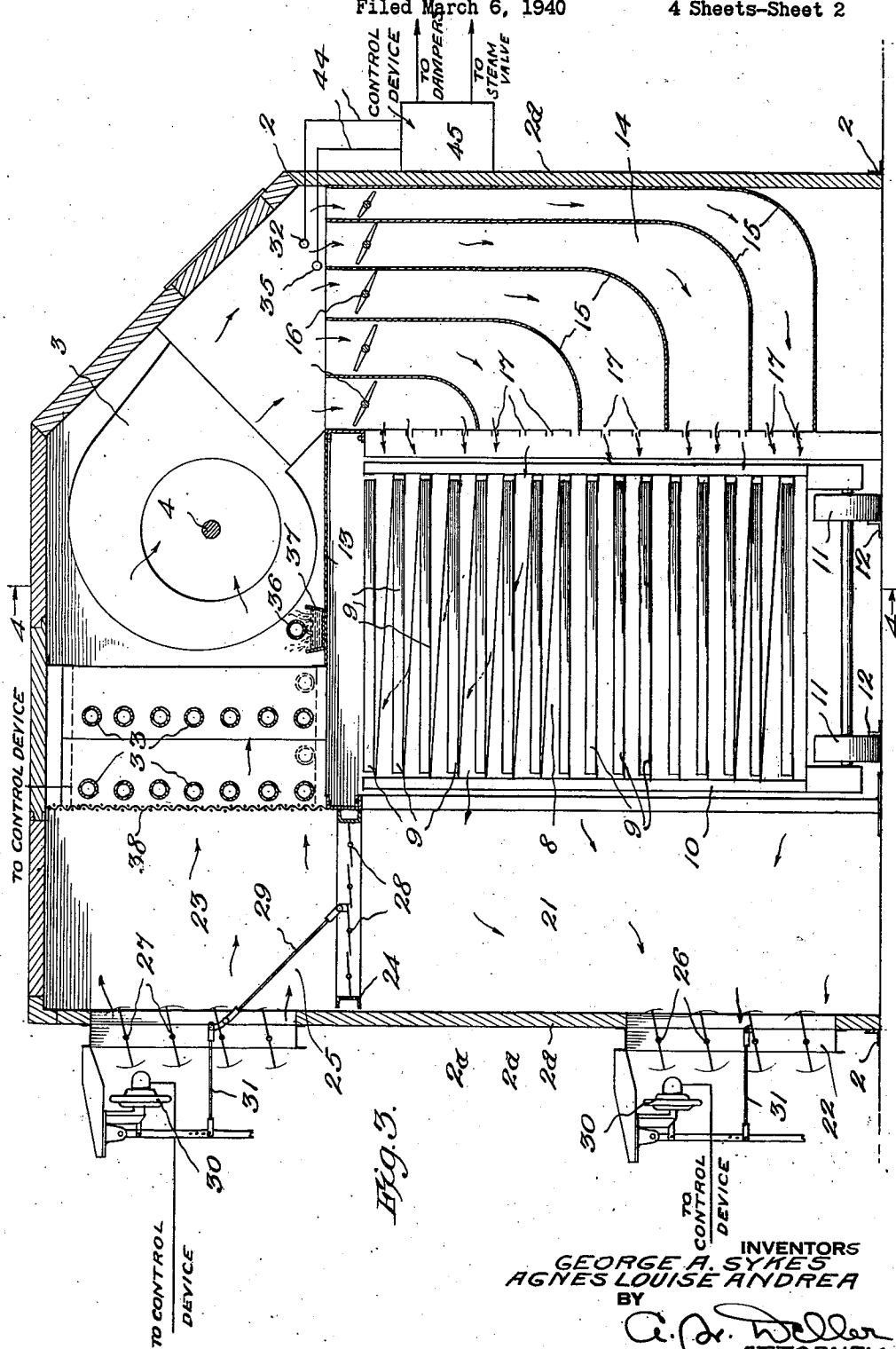
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PROCESS FOR DEHYDRATING WATER-CONTAINING MATERIALS

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4 Sheets-Sheet 2



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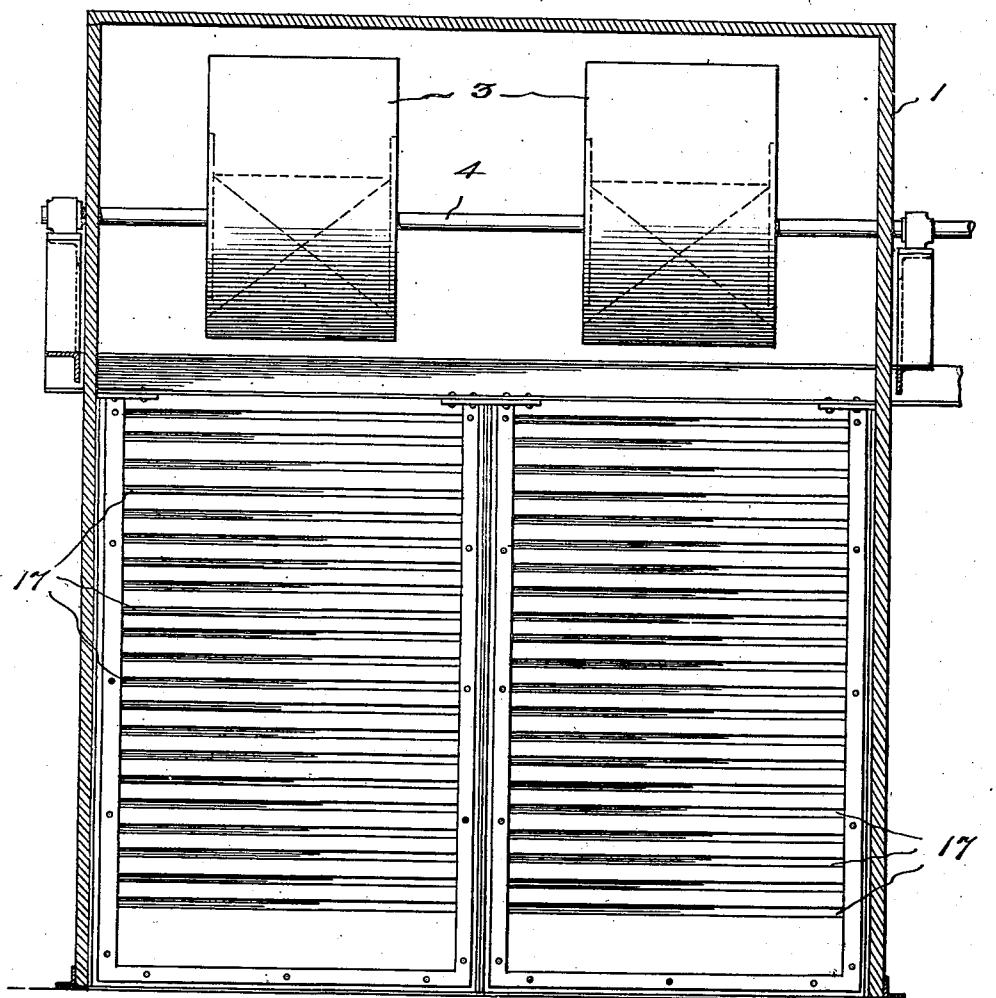
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PROCESS FOR DEHYDRATING WATER-CONTAINING MATERIALS

Filed March 6, 1940

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Fig. 4.



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PROCESS FOR DEHYDRATING WATER-CONTAINING MATERIALS

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4 Sheets-Sheet 4

Fig. 5.

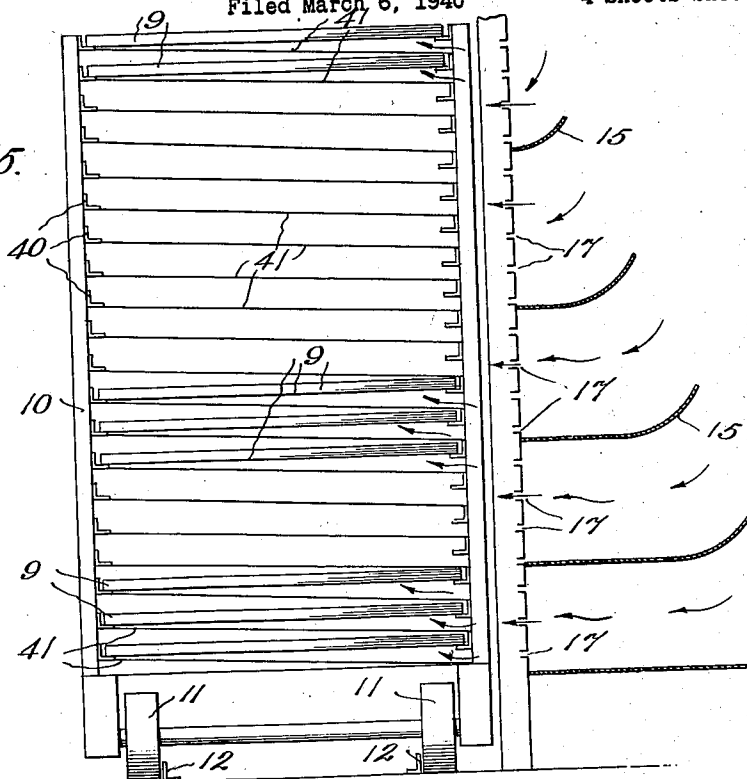
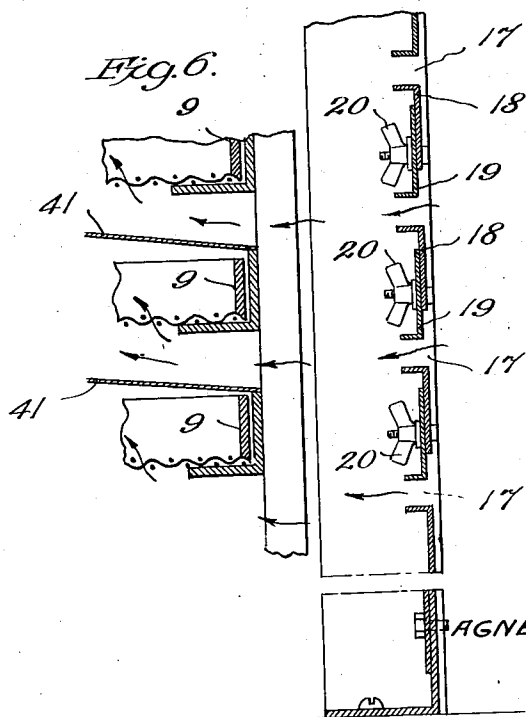


Fig. 6.



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2,318,027

PROCESS FOR DEHYDRATING WATER-CONTAINING MATERIALS

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Application March 6, 1940, Serial No. 322,504

4 Claims. (Cl. 34—26)

The present invention relates to a process for dehydrating water-containing materials, and, more particularly, to a novel and improved process for dehydrating foodstuffs in such a manner as to retain their structure, integrity, and vital principles, and to the products of such process.

As those skilled in the art know, the art of dehydrating is a very old one, particularly the art of dehydrating or drying water-bearing materials, such as foodstuffs, which has been practiced to some extent at least throughout the entire history of the human race. A large number of methods and devices has been developed for drying moist and water-bearing materials. Due to the complexity of the problem, however, all of these prior methods provided an inferior product. The extreme complexity of the problem will be readily understood if it is considered that during dehydration food products are greatly exposed to impregnation with bacteria, fungi, spores, and the like carried by the air which rendered the dehydrated products extremely dangerous to health and frequently caused early deterioration of the products. Similar difficulties were experienced with oxidation of the materials to be dehydrated prior and particularly during the process of dehydration. One of the most grave difficulties encountered in dehydration was the so-called "case-hardening" of the materials. In other words, the materials dried first at the surface giving a case-hardening effect. As the drying process continued, the internal water expanded due to the heat and, being unable to evaporate through the pores of the already hardened surface, rupture of the internal cell structure occurred, causing checking and cracking. Thus, dehydration and drying as heretofore practiced was very destructive of the original cellular composition of the materials dried, and consequently an attempt to restore the materials to their original condition by adding water could not bring back the color and flavor of the fresh materials. To counteract this most serious difficulty, it has been suggested to introduce moisture, water vapor, etc. under various operating conditions, but these prior suggestions, although somewhat alleviating the difficulty, failed to provide a full solution of the problem. Conventional dehydrated materials, particularly foodstuffs, had an unattractive appearance and even after restoring the original water content did not even approach the appearance, flavor, and wholesomeness of the fresh materials. On the other hand, dehydrated materials had a number of unques-

tionable and important advantages. Thus, a dehydrated material has in most cases less than 15 or 20% of the weight of the original product, requires only a fraction of the space for storage and, if properly made, could be kept in storage for a number of years without deterioration. As a result, dehydration was practiced on a large scale since time immemorial, but due to the inferior quality of the dehydrated products, especially since the introduction of modern canning and freezing methods for the preservation of food, it has never attained the importance in the food economy of the human race to which it is entitled.

From the foregoing considerations, it will be apparent that the art was confronted with a problem of extreme seriousness and of incalculable importance, for which so far no wholly satisfactory solution has been found, especially insofar as commercial production on an industrial scale of acceptable products capable of restoration to their original condition has been concerned.

We have discovered a simple and completely satisfactory solution of the outstanding problem.

It is an object of the present invention to provide a process for dehydrating water-containing materials which completely eliminates the disadvantages and inconveniences of conventional processes and at an economy of time, labor and fuel and packaging costs unique.

It is another object of the invention to provide a novel and improved process for dehydrating water-containing materials, particularly foodstuffs, which preserves the cellular structure, appearance, taste, flavor, wholesomeness and vital principles of the original material to such an extent that the dried or dehydrated materials may be restored to substantially their original condition by restoring their original content of water.

A further object of the invention is to provide a process for dehydrating water-containing organic materials during which the material is subjected to a plurality of periods of treatments during each of which the temperature, the humidity, the velocity of the gaseous medium, such as heated air, to which the material is exposed, are critically controlled, to avoid case-hardening, oxidation, and other difficulties experienced in prior processes.

Still another object of the invention is to provide a process for dehydrating foodstuffs of various character involving rigid control of the humidity, temperature, including convective and

conductive heat flow, and radiant heat over and below the materials processed, gas velocity and other governing factors throughout the entire drying period in accordance with a predetermined sequence, whereby the dried materials produced are capable of restoration to their original condition by steeping in water.

It is also within the contemplation of the invention to provide an apparatus for carrying the process of the invention into practice which is capable of providing the control of humidities, temperatures and velocities of the heat currents, and of the radiant heat desiccation required by the principles of the invention and which is adapted to dehydrate large quantities of materials within an unprecedentedly short time and at a heretofore unattainable low cost on a practical and industrial scale.

The invention also contemplates a novel type of dehydrated product, particularly dehydrated foodstuffs, having a fraction of the weight and of the space requirements of the fresh product, which can be stored indefinitely in ordinary storage space without refrigeration and which by the addition of water may be restored to substantially the original size, shape, and appearance of the fresh product and which as far as its taste, flavor, nutritiveness, and the presence of vital principles, such as vitamins, is concerned, is closely similar to the fresh material.

Other and further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 illustrates a front elevational view of a preferred embodiment of a dehydrator for carrying the principles of the invention into practice;

Fig. 2 shows a plan view of the dehydrator illustrated in Fig. 1;

Fig. 3 depicts a vertical sectional view, having parts in elevation, of the dehydrator shown in Fig. 1;

Fig. 4 shows a vertical sectional view taken on line 4-4 of Fig. 3;

Fig. 5 is a front elevational view of one of the trucks bearing a plurality of superposed trays to be employed in connection with the apparatus illustrated in Figs. 1 to 3; and

Fig. 6 is a sectional detail view, somewhat fragmentary in character and at an enlarged scale, of the adjustable slots for the selective control of the drying gases over the individual trays.

Broadly stated, according to the principles of the invention, a drying chamber is provided within which the materials to be dried such as vegetables, fruits, and the like, are spread on a plurality of superposed trays for drying and within which a circulation of heated air is maintained. The upper portion of the chamber has the air-circulating means or fans mounted therein while the lower part of the chamber is divided into three parts, the middle one of which contains the stack of superposed drying trays. To one side of these stacks of trays is a plenum chamber which communicates with the outlet of the fans. On the other side of the stack is provided an exhaust chamber having an exhaust duct to the atmosphere and having a vertical passage for the recirculation of air to the intake of the fans. The flow of the moisture-laden air from the exhaust chamber to the exhaust duct and to the vertical passage is controlled by means of dampers. If the air in the exhaust chamber does not contain too much moisture, then it may be recirculated in whole or in part.

Suitable heating means such as steam heating pipes or coils, electric heating elements, gas or oil heaters, and the like, are provided for raising the temperature of the recirculated air. After the air passes through these heating means and is heated to the desired temperature, the fans suck the heated air in through inlet ports and then deliver it under pressure through the outlet ports to the plenum chamber and to the stack of superposed trays. If the air which is being recirculated does not contain sufficient humidity then moisture may be added, for example, by means of an open steam pipe, or of a "pet cock." For guiding the air from the outlet of the fan to the stack of trays, a plurality of deflectors may be positioned in the plenum chamber although in some cases these deflectors may be omitted. A plurality of dampers mounted at the upper part of the deflectors may be used to control the amount of air passing between each pair of deflectors and in this manner control the amount of air going to the various sets of trays. For controlling the temperature and humidity within the drying chamber, a humidity and temperature control device is used capable of opening and closing dampers regulating the circulation of air through the dehydrating chamber and controlling the operation of the heating and humidifying means, as it will be described more fully hereinafter.

The essence of the process of the invention resides in subjecting the materials to be dehydrated to a plurality of cycles of treatments during which the temperature, the humidity and the velocity of the drying gases, e. g., hot air, is maintained within critically adjusted limits. In carrying the dehydration process of the invention into practice, the vegetables or fruits to be dried are peeled and pared and then are sliced, or shredded. The thus prepared vegetable or fruit is spread on perforated or screened trays, preferably made of aluminum. These trays are superimposed upon each other on a truck which is wheeled into the drying zone of the drying chamber. At the start, the air has a relatively low heat and a relatively high humidity. Slow circulation of air under these conditions is continued for a short period. Following the initial operation, the air under circulation is adjusted to a high heat and high humidity for a long period and the speed of circulation is increased. To complete the drying, the air is then circulated at a reduced heat and reduced humidity. This reduced heat and humidity can be adjusted until the final temperature and final humidity have been reached. Thus, the drying period may end with air being circulated at medium heat and low humidity. When the vegetable or fruit has been dried, it is removed from the drying chamber and then placed in a storage chamber which is maintained at a desired temperature and humidity or may be packed in appropriate containers under suitable conditions.

The invention will now be more fully described in conjunction with the accompanying drawings.

Referring now more particularly to Figs. 1 to 4 of the drawings, a preferred embodiment of the principles of the invention into a dehydration machine is illustrated. The dehydration machine essentially comprises a casing 1 constituted of a metal frame 2 forming a support for a plurality of panels 2a. For compactness, the chamber is practically cubicle-shaped with the exception of one side of the upper portion, which is sloped. Circulation of the gases within drying chamber

1 is obtained by means of two fans 3 which may be jointly actuated by means of a common shaft 4, having a pulley 5 mounted on one end thereof driven by an electromotor 6 by means of a belt 7 whereby predetermined and accurately controlled gas velocities may be maintained within the chamber. The lower portion of the chamber is divided into three parts, or compartments. The center compartment 8 contains the stack of superposed drying trays 9 which for convenience of handling are mounted on a truck 10 having wheels 11 running on a pair of rails 12. A partition wall 13 separates the top of the center compartment from the compartment containing the fans. To one side of the stacks of trays is a plenum chamber 14 which is in communication with and is directly connected to the outlet of the fans. For guiding the air from the outlet of the fans to the stack of trays, a plurality of deflectors 15 are positioned in the plenum chamber which convert the substantially vertical flow of drying air into a horizontal flow. A plurality of dampers 16 are adjustably mounted at the upper terminal portions of deflectors 15 and may be used to control the amount of air passing between each pair of deflectors and in this manner control the amount of air going to the various sets or trays.

It has been found that accurate control of the amount of air going to the various trays is of critical importance. This amount may be to some extent adjusted by setting dampers 16 into such positions that all of the trays, including the highest and the lowest one, receive the preferred and desirable amount of air, in order to obtain uniform dehydration on all of the trays. In addition to this possibility of adjustment, a further adjustment is provided by incorporating adjustable slots 17 before the trays between the plenum chamber and the center chamber. As it will be best observed from Fig. 6 of the drawings, these adjustable slots are provided by mounting a plurality of pairs of L-shaped plates in horizontal and parallel-spaced position between the center and plenum chambers and in front of the stack of trays in the center chamber. One of each pair of such plates 18 is rigidly connected to the vertical rails forming part of the machine frame by means of welding or riveting. The other one of each pair of such plates 19 is mounted in an inverted position and has an elongated slot at each end thereof so that it can be adjusted to any desired position and may be fixed in such position by means of a wing-nut 20. Thus, each pair of L-shaped plates defines a slot with the adjoining pair of plates, each of said slots being individually and accurately adjustable and is adapted to be fixed at a predetermined width. From the foregoing considerations, it is apparent that while dampers 16 at the upper portion of deflector plates 15 permit close adjustment of the amount of drying air passed to the various trays, the provision of the adjustable slots before the individual trays makes it possible to separately adjust the drying air for each individual tray whereby a control of heretofore unattainable accuracy is provided. Experiments have demonstrated that the extreme accuracy of this adjustment is one of the critically important factors in the production of a dehydrated product of high and uniform quality.

To the left side of the stack of trays is provided an exhaust chamber 21 having an exhaust duct 22 which is preferably connected to the external atmosphere outside of the building in which

the dehydrating machine is located. Above exhaust chamber 21 is an intake chamber 23 which is in communication with both the upper portion of the exhaust chamber and with the intake side of the fan through a channel 24. In addition to this, the intake chamber is also provided with an opening or port 25 through which air may be admitted from the proximity of the machine into the circulatory flow within the machine.

The circulatory flow within the various chambers of the dehydrating machine is controlled by means of three dampers of which damper 26 is mounted in the external wall of exhaust chamber 21 and controls the discharge of air from the machine into the exterior atmosphere, damper 27 is mounted into the external wall of the intake chamber and controls the admission of air within the building into the machine, and damper 28 is mounted in channel 24 between exhaust chamber 21 and intake chamber 23 and controls the circulatory flow within the machine. Each of these dampers comprises a plurality of pivotally mounted plates or vanes which are connected for joint operation by means of a lever mechanism and may be jointly displaced by means of suitable actuating elements. In dampers 26 and 27 these actuating elements include a small electric motor 30 which displaces the vanes by means of a lever rod 31. The operation of damper motors 30 is controlled by means of a wet bulb thermometer or a similar humidity-responsive device 32, as those skilled in the art will readily understand. It will be noted that dampers 26 and 27 are simultaneously and synchronously actuated by their respective motors and that they are both in the open or closed position at the same time. On the other hand, the third damper 28 regulating the flow of air between the exhaust chamber and the intake chamber is connected to damper 27 by means of a lever rod 29 for to be automatically actuated in the opposite direction so that when for example damper 27 is open, damper 28 is closed, and vice versa.

Between the intake side of fans 3 and intake chamber 23 are provided heating means in the form of two banks of steam heating pipes or coils 33. Of course, instead of steam, heating with electricity, gas or oil may be employed, if preferred. Valve means are associated with these steam heating pipes to control the temperature within the chamber and to provide adjustable reheating of the recirculated air. These valve means are controlled by suitable thermostatic means such as a dry bulb thermometer 35 located at the outlet side of the fans. If the air which is being recirculated does not contain sufficient humidity, then moisture may be added by means of an open steam pipe, or "petcock," 36 and an associated water tank 37 which are located between second heater 34 and fans 3. Wet bulb thermometer 32 and dry bulb thermometer 35 are connected by means of lead wires 44 to a control device or box 45 which is electrically associated with motors 30 of the dampers and with the valve actuating means of steam heating pipes 33 (not shown), to control the humidity and temperature conditions within the dehydrating chamber. In view of the fact that this control system is of conventional character, those skilled in the art are familiar with its operation. A screen 38 is provided between intake chamber 23 and the intake side of the fans to catch impurities suspended in the air and to prevent deposition thereof on the heating means or introduction thereof into the circulatory flow.

The construction of the truck bearing the trays on which the materials to be dehydrated are introduced into the dehydrating chamber will be best understood from Fig. 5. The truck comprises a frame 10 constituted of iron rails resting on wheels 11. A plurality of angle irons 40 are mounted in the horizontal position at the two sides of the truck frame and are adapted to support trays 9. The trays comprise a wooden or metal frame covered with a wire mesh of suitable coarseness to facilitate passage of the gases therethrough. It has been found that the best material for making the wire mesh is aluminum, as aluminum is not attacked by the various acids contained in the materials to be dehydrated and does not impart any taste to the materials treated. In some cases, such as when dehydrating apples, it is advantageous to coat the wire mesh of the trays with high melting point paraffin alone or containing a high melting point wax, etc., to prevent sticking of the apples to the wire. Between the various trays baffle sheets 41 are provided which extend from the bottom of an upper shelf to the top of a lower shelf. These baffle sheets form a channel through which the circulated air can pass. These baffle sheets likewise are able to catch any condensate from the tray on an upper shelf and to carry such condensate, leakage, etc. to the side of the truck, thus preventing such condensate or leakage from dropping upon the vegetable, fruit, etc. to be dehydrated on the tray below. The trays are so spaced on the truck that the streams of dehydrating air defined by adjustable slots 17 of the plenum chamber will be directly introduced into the space between the trays and are caused to pass through the materials on the trays.

From the foregoing description, the operation of the dehydrating machine embodying the invention will be readily understood by those skilled in the art. The vegetable or fruit is first prepared by peeling, paring, slicing, shredding, etc., or subjected to other operations of similar character, if necessary, and is spread on the perforated or screen trays which are stacked in superposed relation on the trucks. In the preferred embodiment of the invention described and illustrated, two of such trucks are rolled into the drying chamber and doors 42 at the two ends of drying chamber 1 are closed to seal the chamber. As has been explained in the foregoing, to the one side of the trucks adjacent to the plenum chamber, a panel is provided with a series of superposed adjustable slots 17, which are located in alignment with the space between the trays. These slots are adjusted and are locked in this adjusted position, in accordance with the character of the materials to be dehydrated so that the proper amount of air can be admitted to each of the trays. In general it is desired to have a uniform stream of air passing through the slots at approximately the same velocity, thereby delivering approximately the same amount of air to each tray.

Depending upon the fruit, vegetable or other material to be dried, the index arms of the dual controller controlling the humidity and the temperature within the dehydrating chamber are set to the dry bulb and wet bulb thermometer readings corresponding to the desired conditions of temperature and humidity within the drying chamber. The two fans 3 are then started in operation by energizing electromotor 6. The air will be circulated at the temperature and the humidity set by the index arms. Usually, at the

start of the operations, the wet bulb thermometer is too low and therefore the wet bulb thermometer acts through its thermal system to open the heater spray from the open steam pipe 36 and to close the fresh air and exhaust dampers 27 and 26, respectively, while opening the recirculation damper 28. The dry bulb thermometer likewise acts through its thermal system to open the steam valves controlling the steam to heaters 33. In this manner, the temperature and humidity of the air being recirculated is adjusted to the desired temperature and humidity, and a closed circulatory flow is maintained within the drying chamber.

During the recirculation of the air, the stream of air emerging from fans 3 passes over dry bulb thermometer 35 and wet bulb thermometer 32 and then into plenum chamber 14. In the plenum chamber, the stream of air is divided into a plurality of individual streams by means of deflectors 15 and are guided to the plurality of superposed adjustable slots 17 and pass into the spaces underneath each tray 9. Inclined baffles 41 between each pair of adjoining trays cause the air to flow upward through the material on each perforated tray into the space above the tray and then out into exhaust chamber 21. From the exhaust chamber, the air flows partially or wholly to exhaust duct 22 in case damper 28 is closed or to the vertical passage communicating with intake chamber 23, provided damper 28 is open. Fresh air may be admixed with the recirculated air. It is to be noted that this fresh air comes from the room in which the drying chamber is located and is not taken from outdoors.

When the recirculated air passes through the material on the tray, its temperature falls and its humidity increases. The dual controller automatically adjusts the steam valve and the various dampers to control the temperature and the humidity of the air. In this manner, the recirculated air which is delivered to the trays is maintained practically constant with respect to temperature and humidity. It is to be noted that the minimum humidity of the system is limited by the moisture content of the fresh air and that the maximum temperature is limited by the heating capacity of heaters 33, the steam pressure, the percentage of cold fresh air admitted through damper 27 for securing the desired humidity, and various other factors which are readily appreciated by those skilled in the art.

In carrying the dehydration process embodying the present invention into practice, the operating conditions are so adjusted that at the start the air has a low heat and a high humidity. Slow circulation of air under these conditions is continued for a predetermined and relatively short period of time. Following this initial operation, the air under circulation is adjusted to a high heat and high humidity for a relatively long period, and at the same time the speed of circulation is increased. To complete the drying, the air is then circulated at a reduced heat and reduced humidity. This reduced heat and humidity can be adjusted until the final temperature and final humidity have been reached. Thus, the drying period may end with air being circulated at medium heat and low humidity. When the vegetable or fruit has been dried, it is removed from the drying chamber and is placed into a storage chamber which is maintained at the desired temperature and humidity, or which

may be packed in appropriate containers under suitable conditions.

Generally speaking, the preferred operations, included in the dehydration process embodying the present invention may be listed as follows:

1. Peeling and paring the vegetables or fruit.
2. Slicing, cubing and shredding.
3. Spreading on perforated or screen trays.
4. Superimposing the trays in the drying chamber.

5. Recirculating a current of air at low heat (say at about 150-160° F.) and high humidity (say about 35-50%) pulled slowly through the trays for a short period (usually less than about 1 hour).

6. Recirculating a current of air at high heat (say at about 170-190° F.) and high humidity (say about 30-50%) pulled rapidly through trays for a long period (usually more than about 1 hour).

7. Recirculating a current of air at reduced heat (say at about 170° F.) and reduced humidity (say about 20-35%) pulled at same rapid velocity for about an hour. This step may sometimes be eliminated, in the discretion of the operator, depending upon the fruit or vegetable being dried and upon particular conditions and circumstances.

8. Recirculating a current of air at medium heat (say at about 140-170° F.) and low humidity (say about 15-20%) pulled at the same high velocity until the vegetables or fruit are dried.

9. Removing the desiccated food product.

The preferred drying operation may be divided up into an initial or short period, an intermediate or long period, a supplementary or medium period, and a final period. In some instances, the supplementary or medium period may be eliminated. These periods may be illustrated by the following flow sheet:

Initial or short period

Slow fan
Low heat (150-160° F.)
High humidity (35-50%)
Less than 1 hour

Intermediate or long period

Full fan
High heat (170-190° F.)
High humidity (30-50%)
More than 1 hour

Supplementary or medium period

Full fan
Medium heat (150-170° F.)
Reduced humidity (15-30%)
Time to suit

Final period

Full fan
Medium heat (140-170° F.)
Low humidity (5-15%)
Balance of drying time

For the purpose of giving those skilled in the art a better understanding of the invention, the following illustrative examples may be given:

Example No. 1

About 1000 pounds of cherries are washed and after removal of the stones and stems are spread on the trays of the trucks wheeled into the drying chamber. The initial treating period utilizes a starting temperature of about 150° F., a relative humidity of about 30% and a slow fan for about one-half hour for the initial or short period. During the intermediate treatment, the temperature is raised to about 190° F., and a relative humidity of about 30% is maintained with a full fan for about 2 hours. A supplementary or medium period is used and a temperature of about 170° F. and a relative humidity of about 20% is employed with a full fan for about 1 hour. During the final period, a temperature of about 170° F. and a relative humidity of about 15% is maintained with a full fan for the balance of the drying time. After the final period, the dehydrated cherries may be kept in a storage chamber or may be packed as desired.

Example No. 2

About 1000 pounds of apples are pared and sliced and are then spread on the trays introduced into the dehydrating chamber. An initial treating period is used with a temperature of about 160° F. and a relative humidity of about 30% with a slow fan for about one-quarter hour. The intermediate period then follows with a temperature of about 190° F. and a relative humidity of about 25% with a full fan for about 2 hours. The supplementary or medium period is omitted, and during the final period a temperature of about 185° F. and a relative humidity of about 10% is maintained with a full fan for the balance of the drying time.

Example No. 3

About 1000 pounds of potatoes are pared and sliced and are then spread on the trays introduced into the dehydrating chamber. An initial treating period is used with a temperature of about 150° F. and a relative humidity of about 35% with a slow fan for about 15 minutes, this being followed by a second initial treating period with a temperature of about 165° F. and a relative humidity of about 35% with a slow fan for another 15 minutes. The intermediate period then follows with a temperature of about 160° F. and a relative humidity of about 30% with a medium fan for about 30 minutes. A supplementary or medium period is used and a temperature of about 160° F. and a relative humidity of about 30% is employed with a full fan for about 30 minutes. During the final period, a temperature of about 150° F. and a relative humidity of about 25% is maintained with a full fan for the balance of the drying time.

In the event that it is desired to blanch vegetables or fruits, blanching steam may be directly admitted to the trays on the truck within the drying chamber. Likewise, in some cases it is desirable to treat the vegetables or fruits with sulphur dioxide fumes or other vapors or gases for a suitable period of time. For this purpose it is preferred to make provision for shutting off the drying chamber proper from the fans and from the motor as the heavy steam used in "blanching" is injurious to the fan bearings and the sulphur dioxide fumes are likely to strongly attack the motor fittings with disastrous results. In this manner, it is possible to carry out these supplementary treatments within the drying ap-

paratus and the cost and delay caused by additional handling may be eliminated.

The product produced by the process embodying the present invention is unique in character and has properties vastly superior to those of conventional dehydrated products. While prior art dehydrated products are usually powdery, flaccid, leathery, colorless and lacking flavor, the products prepared in accordance with the principles of the invention, can be soaked in water and they will return approximately to their natural size and color and possess the natural flavor and wholesomeness of the original product. We have found that in conventional drying and dehydrating processes, the cell membranes of the materials become "case-hardened" through the necessarily high drying temperatures, causing the internal water to expand and to burst open the cell walls whereby the volatiles are lost and air entering the ruptured cells causes oxidation and destruction of the vitamins, chlorophyll and other substances upon which the nutritive value of fruits or vegetables depends. In contrast to this, the carefully controlled sequence of the treating steps of the invention involving the maintenance of critical temperature, humidity and gas velocity conditions for predetermined periods of time, completely eliminates these disadvantages of prior dehydrated materials and permits the production of dehydrated materials having all of the desirable properties of the original materials.

We believe that these remarkable and unique properties of the dehydrated products prepared in accordance with the principles of our invention are due to the fact that we carefully maintain our treating conditions, including temperatures, below a critical limit which, for convenience, may be called the "thermal death point" of the materials to be dehydrated. We found that when this critical limit is surpassed, "case-hardening" occurs with the consequent deterioration and destruction of the cellular structure characteristic of conventional dehydrated products. If the cells are broken open, air entering the ruptured cells destroys the chlorophyll, carotene and other vitamins and vital principles. Of course, this critical limit varies with the material to be dehydrated, and what is a suitable maximum treating temperature for one material would be excessive and disastrous for another. For example, apple will stand 190° F. without any ill effects while 160° F. is about all that may be given to potato or cabbage. The fact that the treating temperatures of the process embodying the present invention are below the "thermal death point" of the various fruits and vegetables is proved by the observation that seeds dried by the process of the invention will grow again in a suitable surrounding. Thus, for example, tomato seeds have grown for 4 or 5 generations after drying each generation by means of the apparatus and method embodying the invention.

Microscopic examination of the cellular structure of the products of the invention shows that in the products embodying the present invention, the cellular structure remains substantially intact. Thus, photomicrographs of various fruits and vegetables were prepared both before and after dehydration and it was found that practically no change occurred in the size, shape, arrangement and integrity of the cells. Clearly, this heretofore unattainable intactness of the cellular structure of our dehydrated products and

their freedom from cracks, splits, etc., is responsible for their remarkable properties outlined in the foregoing.

It will be noted that the present invention provides a number of important advantages. Thus, first of all, a novel and improved process for dehydrating foodstuffs is provided which preserves the cellular structure, appearance, taste, flavor, wholesomeness and vital principles of the original material to such an extent that the dried or dehydrated materials may be restored to substantially their original condition by restoring their original content of water.

It is also to be observed that the dehydrated products of the invention have in most cases less than about 15 or 20% of the weight of the original product, require only a fraction of the space for storage and can be kept in storage for a number of years without deterioration. Thus, for example, one bushel of carrots in the dehydrated condition is reduced in volume to about ½ gallon and ten pounds of tomatoes are reduced in volume to about ½ pint.

Moreover, the process of the invention is extremely simple in character and is capable of dehydrating large quantities of materials within an unprecedentedly short time and at a heretofore unattainable low cost on a practical and industrial scale. Thus, in addition to apples, cherries and potatoes, the process embodying the invention may advantageously be used for dehydrating various other foodstuffs including fruits and vegetables. For example, spinach, beets, parsley may be dehydrated in three treating periods involving treating temperatures of 150° to 160° F., 160° to 175° F. and 145° to 175° F., respectively and humidities of 25% to 35%, 25% to 35%, 15% to 20%, respectively. Blueberries, peaches, carrots, peppers, string beans, cabbage, celery, wax beans and tomatoes may be dehydrated in four treating periods involving treating temperatures of 140° to 160° F., 160° to 185° F., 150° to 185° F. and 145° to 175° F., respectively, and humidities of 25% to 45%, 25% to 45%, 15% to 40% and 15% to 30%, respectively. Turnips, onions and peas may be dehydrated in five treating periods involving treating temperatures of 150° to 160° F., 160° to 180° F., 160° to 180° F., 150° to 170° F., and 145° to 170° F., respectively, and humidities of 35% to 40%, 30% to 40%, 25% to 35%, 20% to 25% and 10% to 15%, respectively.

Although the present invention has been described in connection with a preferred embodiment thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the present invention. We consider all of these variations and modifications as within the true spirit and scope of the present invention as disclosed in the foregoing description and defined by the appended claims.

We claim:

1. The process of dehydrating foodstuffs which comprises establishing a circulatory flow of air within a closed space and in contact with the foodstuffs to be dehydrated, maintaining said flow at a temperature of about 140° to about 180° F. and at a humidity of about 25% to about 50% for a first treating period of the order of about one-quarter hour to about one hour, maintaining said flow at a temperature of about 160° to about 190° F. and at a humidity of about 25% to about 50% for a second treating period of the order of about one-half hour to several hours

and longer than said first treating period, and subsequently maintaining said flow at a temperature of about 140° to about 170° F. and at a humidity of about 5% to about 30% for the balance of the drying time whereby a dehydrated product free from case-hardening effects and retaining the original cellular structure is obtained, said dehydrated product being adapted to be substantially restored by the addition of water to a product having the appearance, size, texture and flavor of the fresh foodstuffs.

2. The process of dehydrating foodstuffs which comprises establishing a circulatory flow of air within a confined space and in contact with the foodstuffs to be dehydrated, maintaining said flow at a temperature of about 140° to about 160° F. and at a humidity of about 25% to about 50% for an initial treating period of the order of about one-quarter hour to about one hour, maintaining said flow at a temperature of about 160° to about 190° F. and at a humidity of about 25% to about 50% for an intermediate treating period of the order of about one-half hour to several hours and longer than said initial treating period, maintaining said flow at a temperature of about 150° to about 170° F. and at a humidity of about 15% to about 30% for a supplementary period of the order of about one-half to about one hour, and subsequently maintaining said flow at a temperature of about 170° to about 190° F. and at a humidity of about 5% to about 30% until said foodstuffs are completely dehydrated and a dehydrated foodstuff free from case-hardening effects and retaining the cellular structure of the original foodstuffs is obtained, said dehydrated foodstuff being adapted to be substantially restored by the addition of water to a product having the appearance, size, texture and flavor of the fresh foodstuffs.

3. The process of dehydrating foodstuffs which comprises establishing a circulatory flow of air within a confined space and in contact with the foodstuffs to be dehydrated, maintaining said flow at a temperature of about 150° to about 160°

5 F. and at a humidity of about 30% to about 45% for a period of the order of about one-quarter to about one hour, maintaining said flow at a temperature of about 180° to about 190° F. and at a humidity of about 30% to about 40% for a period of the order of about one-half to about two hours, and subsequently maintaining said flow at a temperature of about 160° to about 170° F. and at a humidity of about 15% to about 20% until said foodstuffs are completely dehydrated and a dehydrated foodstuff free from case-hardening effects and retaining the cellular structure of the original foodstuffs is obtained, said dehydrated foodstuff being adapted to be substantially restored by the addition of water to a product having the appearance, size, texture and flavor of the fresh foodstuff.

4. The process of dehydrating foodstuffs which comprises establishing a circulatory flow of air within a confined space and in contact with the foodstuffs to be dehydrated, maintaining said flow at a temperature of about 150° to about 160° F. and at a humidity of about 30% to about 45% for a period of about one-quarter to about one hour, maintaining said flow at a temperature of about 180° to about 190° F. and at a humidity of about 30% to about 40% for a period of the order of one-half to a few hours, reducing said heat to about 170° F. and said humidity to about 20% to about 35% for a supplementary treating period of the order of about one-half to about one hour, and subsequently adjusting said temperature to about 160° to about 170° F. and said humidity to about 15% to about 20% until said foodstuffs are completely dehydrated and a dehydrated foodstuff free from case-hardening effects and retaining the cellular structure of the original foodstuffs is obtained, said foodstuff being adapted to be substantially restored by the addition of water to a product having the appearance, size, texture and flavor of the fresh foodstuffs.

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