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(54) Title: A PROCESS FOR CONTINUOUS, DELICATE VACUUM DRYING A LIQUID AND A DRYING APPARATUS FOR USE IN THE PROCESS		
(57) Abstract Liquids susceptible to heat damage and having a content of dissolved and/or suspended solids are dried by vacuum while being distributed onto the surface of spherical conveying means (6), the energy required for the evaporation being emitted by a microwave field. The conveying means are produced from a material which only to a small degree is heated by the microwaves. A drying apparatus for carrying out the process includes a vacuum-sealed container (1) through which the conveying means (6) are made to circulate, thereby passing a zone surrounded by a material that is well microwaves penetrable and around which microwaves producing members are located. At the top portion of the container members (7) are provided for the supply of conveying means and liquid to be dried and at the bottom portion members (8) are provided for discharging conveying means and powdery material obtained by the drying.		

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A Process for Continuous, Delicate Vacuum Drying a Liquid and a Drying Apparatus for Use in the Process.

This invention relates to a process for continuous, delicate vacuum drying a liquid having a content of dissolved and/or suspended solids, according to which the liquid is distributed on the surface of substantially spherical conveying means and are dried thereon to a powder that is separated from the conveying means.

Moreover, the process relates to a drying apparatus to be used in the carrying out of said process.

In most prior drying processes the energy necessary to obtain the desired evaporation is supplied by bringing the material to be dried into contact either with a heating surface or with a hot drying gas.

In order that the desired energy supply can be effected, it is necessary that the heating surface or the drying gas has a substantially higher temperature than the average temperature desired to be obtained for the material to be dried.

This obviously involves the risk that a local superheating of parts of the material subjected to drying takes place, thereby causing a deterioration of the quality of the resulting product when drying materials susceptible to heat damage.

Also when making use of infrared rays as the source of heat there is a risk of local superheating, since the temperature rises to the highest at the surfaces hit by the rays.

Said risk of local superheating is obviously greatest when drying materials in which temperature differences are only slowly equalized, i.e. in very viscous materials or in materials of a certain structure.

For the drying of such materials methods have therefore been developed, according to which microwaves

are used as the source of heat which, as known, allow for obtaining an increase of temperature of a material in which they are absorbed, the heat energy being generated within the material, so that no contact is required with any surface or any gas having a higher temperature than that desired in the material during drying.

Drying processes making use of microwave heating have particularly been practised in the drying of paste products like spaghetti. Moreover, microwaves energy has been used as a source of heat for the vacuum drying of concentrated fruit juice, the highly viscous, concentrated material on a conveyor belt being passed through the zone of microwaves, thereby effecting a strong bubble formation and drying to produce a powder.

Said type of prior methods of vacuum drying utilizing microwave energy is however not suited for drying proper liquids, i.e. liquids having such a low viscosity as to form a horizontal surface immediately upon being poured into a container or the like.

Drying processes using heating by microwaves have, however, also been suggested as regards liquids of comparatively low viscosity. Thus, GB patent No. 593,806 discloses a process, according to which particularly penicilium-containing substrate is subjected to drying bathwise in vacuum by microwaves heating, the liquid to be dehydrated being placed in a bowl-shaped container subjected to rotation, presumably with a view to enlarge the liquid surface. This process cannot be continuously carried out as a continuous process, and it is time-consuming due to the fact that the diffusion of volatile components through already dried material must take place during the drying process, in particular during the final steps of the process.

It is observed out that with respect to the drying of liquids it is known, see US patent No. 3,653,424, to carry out the drying while the liquid is being

distributed on the surface of conveying means, e.g. spheres, accommodated within a tower through which a stream of hot drying gas is blown. In the continuous carrying-out of said prior drying method the liquid to be dried on the surface of the conveying means is applied at the top portion of the tower and then moved downwards together with said conveying means in counter-flow with the hot drying air. Conveying means and the material obtained by drying are discharged at the bottom of the tower and the spheres are returned to the top of the tower.

Moreover, US patent No. 3,859,734 discloses a method related to the latter of the above mentioned methods, but according to which the drying of the liquid distributed onto the conveying means is effected under subatmospheric pressure. The energy required for the evaporation is supplied by heating the conveying means outside the drying zone. This obviously implies that the conveying means will have a temperature substantially exceeding the temperature to be obtained for the liquid to be evaporated at the moment they get into contact with the liquid to be dried and, consequently, the heating of the liquid will not be so gentle as desired.

Finally, the accepted German patent specification No. 20 58 774 relates to a method of processing solids or liquids in a high-frequency field, e.g. with a view to the drying of the materials concerned. According to this method the material to be dehydrated is mixed with auxiliary means of dielectric material with a view to obtain an improved exploitation of the high-frequency energy. In case the method is used for the drying of liquids, it is thus required that the auxiliary means are heated by the microwaves and the heat generated within the auxiliary means is conventionally transmitted to the liquid by conduction and convection, thereby entailing the disadvantageous results caused thereby with respect

to the risk of heat damage to sensitive products. Actually, the method is only illustrated in connection with the dehydration of materials of a comparatively good thermostability.

It has, however, turned out that a quite particularly gentle and simultaneously economical drying may be obtained by a process of the type outlined in the first paragraph of the present specification, said process according to the invention being characterized in using conveying means made from a material which only to a very small degree absorbs or reflects microwaves, and in that the conveying means onto which the liquid is distributed are continuously passed under subatmospheric pressure through a zone in which a field of microwaves prevails that heats the liquid film distributed onto the surface of the conveying means, the intensity of the field of microwaves, the vacuum and the residence time of the conveying means in said zone being adapted to evaporate the volatile components of the liquid without increasing the temperature of the conveying means to a value exceeding the temperature the liquid on their surface subjected to evaporation attains due to the direct heating of the liquid by microwaves.

In the present specification with claims the term microwaves is used in its widest sense, including microwaves having frequencies in the range from some hundreds to some thousands MHz. Materials exposed to radiation by such waves receive a heating that may occur evenly all over the volume of the material and which, apart from the field intensity in the radiation zone and the frequency of the rays, depends on the dielectric properties of the material.

By selecting conveying means made from a material which is only slightly heated when passing the field of microwaves, it is obtained that the liquid to be dried at no moment and not even locally attains a temperature

exceeding the intended one to provide a suitable rate of evaporation at the subatmospheric pressure used in each individual case.

The temperature increase obtained in a material as a result of microwave absorption may be somewhat uneven in areas having sharp edges. This problem is solved by the process according to the present invention by making use of spherical conveying means so that any portion of the fluid film on the conveying means attains the same temperature.

In a preferred embodiment of the process the liquid is distributed onto the surface of the conveying means while accommodated in the top portion of a vacuum container filled with conveying means or immediately before being fed into it, and the conveying means are then made to pass through a field of microwaves maintained in the container by discharging the conveying means from the bottom of the container, then feeding them back into the top portion of said container.

During the passage of the conveying means downwards through the vacuum container the balls rub against each other and against the walls of the container, thereby entailing the advantageous effect that the pulverized deposits provided on the surface of the conveying means will be substantially dissociated from the conveying means upon reaching the bottom of the container, and the pulverized material obtained by drying may therefore be separated from the conveying means solely by passing the discharged mixture of conveying means and powder across a perforated plate or screen through whose apertures the pulverized material passes. The pulverized material may subsequently be discharged for instance through a sluice sealed by vacuum.

In view of the fact that the drying process according to the invention is particularly gentle, it is particularly suitable for drying liquids sensitive to

heat, e.g. aqueous liquids containing easily denaturable proteins, such as blood, serum, sheet water and eggs or liquids containing flavouring components that are volatile or sensitive to heat, such as coffee or tea.

The process is for instance applicable with respect to liquids concentrated beforehand by evaporation in a known manner.

The invention further relates to a drying apparatus for use in carrying out the process, said drying apparatus being of the type comprising a cylindrical vertical container substantially filled with spherical conveying means onto which the liquid to be dried is distributed, said container being provided at its top portion either with members for separately feeding conveying means and liquid or members for feeding conveying means sprayed beforehand with the liquid to be dried, and being provided at its bottom portion with members for discharging conveying means and dried material, and members for feeding back discharged conveying means into the top portion of the container, said container being sealed by vacuum and provided with members to be connected with a vacuum source, said drying apparatus being characterized in that

a) at least one section of the cylindrical walls of the container is made from a material that is highly microwaves penetrable,

b) microwaves producing members encircling at least part of said section, and

c) the conveying means are made from a material absorbing or reflecting microwaves only to a slight degree.

Said section of the vertical cylindrical walls that must be well microwaves penetrable is expediently prepared from a plastic material while the remainder of the container may appropriately be made from stainless steel. Alternatively, the entire container may be made from plastic material.

In order to ensure a uniform drying of the fluid film prevailing on the conveying means it is preferred to orient the microwaves producing members provided around at least part of the section made from plastic material in such a manner that a homogeneous field of microwaves is yielded in a zone of the container and the members concerned are appropriately shielded by means of a Faraday-cage. Microwaves producing members are well known and applied to a large extent for the heating of articles of food. Examples of such members are magnetrons. Another type of microwaves producing apparatus is designated klystron.

The drying apparatus according to the invention is illustrated in detail by means of the drawing that very schematically shows an embodiment of the apparatus.

In the drawing 1 designates a cylindrical vertical container of which the central section 2 is made from plastic.

A number of microwave emitting members, e.g. magnetrons, surrounded by a Faraday-cage 3 is disposed around said section 2.

The container 1 is over a condenser 4 connected with a vacuum source (not shown) through a conduit 5.

The container 1 is approximately filled with spherical conveying means 6, preferably produced from a plastic material, such as polycarbonate or teflon.

In the illustrated embodiment a liquid distributor 7, that may for instance be constituted by a pressure nozzle, is arranged in the space above the conveying means in the container, the solution or suspension to be dried being distributed through said liquid distributor onto the surface of the conveying means.

The container 1 is provided with a conical bottom through which the conveying means are continuously discharged.

This causes the conveying means moistened with suspension or solution to move downwards through the container under considerable mutual friction. When the wet conveying means pass the section 2 in which a microwave field prevails, the temperature rises in the liquid layer coating the conveying means to a value corresponding to or near to the boiling point of the liquid at the vacuum sustained in the container 1. In view of the fact that the conveying means possess such dielectric properties that they only slightly the microwaves, the temperature of the surface of the conveying means will not exceed the temperature occurring in the liquid layer that covers them.

The material which was initially solved or suspended in the liquid, forms - after the conveying means have passed the zone facing section 2 - a powder layer on the conveying means which, dependent on the nature of the material to be dried, adheres more or less to the surface of the conveying means.

Experiments have shown that the friction effected between the conveying means during their passing through the container and in connection with the discharge of the conveying means is sufficient to release the powder deposits from the conveying means even when drying materials whose drying and handling are generally regarded as troublesome due to the adhesive properties of the materials.

The conveying means discharged from the bottom portion of the container are fed back into the top portion of the container, as schematically illustrated. Any system, known per se, e.g. a system of worms (not shown) may be used for discharging and feeding back the conveying means into the top portion of the container.

In an expedient embodiment the worm discharging the conveying means and the powder obtained by the drying step may be provided at its lower part with a perfo-

rated plate or for instance a vibrating sieve and therebeneath a vacuum proof powder sluice 8, known per se, from which the powder is fed into a collecting container 9.

As an alternative to the nozzle 7 separate members may be provided externally of the container for wetting the conveying means with liquid to be dried before feeding the conveying means into the container 1. Such alternative members may for instance include a container in which the liquid is sprayed onto the conveying means while keeping them moving by mechanical stirring or tumbling.

The proportion between the quantity of liquid supplied to the container and the quantity of conveying means recycled therein and thus also the thickness of the liquid layer on the surface of the conveying means depends, inter alia, on the viscosity and the sensitivity to heat of the liquid, and it is therefore adjusted in each individual case. Experiments have shown that in case of drying blood the quantity of liquid can be adjusted to the quantity of circulating spheres so as to obtain a determined thickness of the liquid layer on the conveying means in the range of 0.2 mm. Moreover, it falls within the scope of general professional knowledge on the basis of preliminary experiments with a given apparatus to determine appropriate values, e.g. as regards supply of electric energy to the microwave forming members, the vacuum, the quantity of recycled conveying means per time unit and the residence time in the field of microwaves as well as the quantity of liquid supplied, in order to obtain the optimal capacity with a view to operational costs and quality of the product.

In view of the fact that the apparatus according to the invention - in contradiction to prior devices effecting a similar cycling of conveying means - is adapted to effect drying under subatmospheric pressure,

it does not need - in contradiction to said prior devices based on air-drying - to be connected with carbon filters or the like to prevent unpleasant smell even when drying products with an evil smell.

Even though the process and the apparatus of the present specification and claims are explained in connection with drying, the apparatus may as well be able to entail advantages when used as an evaporating apparatus in association with distilling processes, i.e. processes in which the desired product is constituted by the liquid phase or fractions thereof.

P A T E N T C L A I M S

1. A process for continuous delicate vacuum drying a liquid having a content of dissolved and/or suspended solids, in which the liquid is distributed onto the surface of substantially spherical conveying means and are dried thereon to a powder that is separated from the conveying means, characterized in using conveying means made from a material which only to a very small degree absorbs or reflects microwaves, and in that the conveying means onto which the liquid is distributed are continuously passed under subatmospheric pressure through a zone in which a field of microwaves prevails that heats the liquid film distributed onto the surface of the conveying means, the intensity of the field of microwaves, the vacuum and the residence time of the conveying means in said zone bein adapted to evaporate the volatile components of the liquid without increasing the temperature of the conveying means to a value exceeding the temperature the liquid on their surface subjected to evaporation attains due to the direct microwave heating of the liquid.

2. A process as claimed in claim 1, characterized in that the liquid is distributed onto the surface of the conveying means while accommodated in the top portion of a vacuum container filled with conveying means or immediately before being fed into it, and the conveying means are made to pass through a field of microwaves maintained in the container by discharging the conveying means from the bottom of the container and feeding them back into the top portion of said container.

3. A process as claimed in claim 1 or 2, characterized in that the powdery material obtained by drying is separated from the conveying means by passing across a perforated plate or sieve through whose apertures the powdery material passes.

4. A process as claimed in any of the preceding claims, characterized in that a liquid is dried having a

content of easily denaturable proteins, preferably a liquid derived from blood, serum, sheet water or eggs or a liquid containing volatile flavouring components.

5. A drying apparatus for use in carrying out the process according to claim 1 and of the type comprising a cylindrical vertical container substantially filled with spherical conveying means onto which the liquid to be dried is distributed, said container being provided at its top portion either with members for separately feeding conveying means and liquid or members for feeding conveying means wetted beforehand with the liquid to be dried and being provided at its bottom portion with members for discharging conveying means and dried material and members for feeding back discharged conveying means into the top portion of the container, said container being vacuum-sealed and provided with members to be connected with a vacuum source, characterized in that

a) at least one section of the cylindrical walls of the container is made of a material that is highly microwave penetrable,

b) microwaves producing members surround at least part of said section, and

c) the conveying means are made from a material which only slightly absorb or reflect microwaves.

6. A drying apparatus as claimed in claim 5, characterized in the microwaves producing members are oriented in such a manner that a homogeneous field of microwaves is formed in a zone of the container and the members concerned are shielded by means of a Faraday-cage.

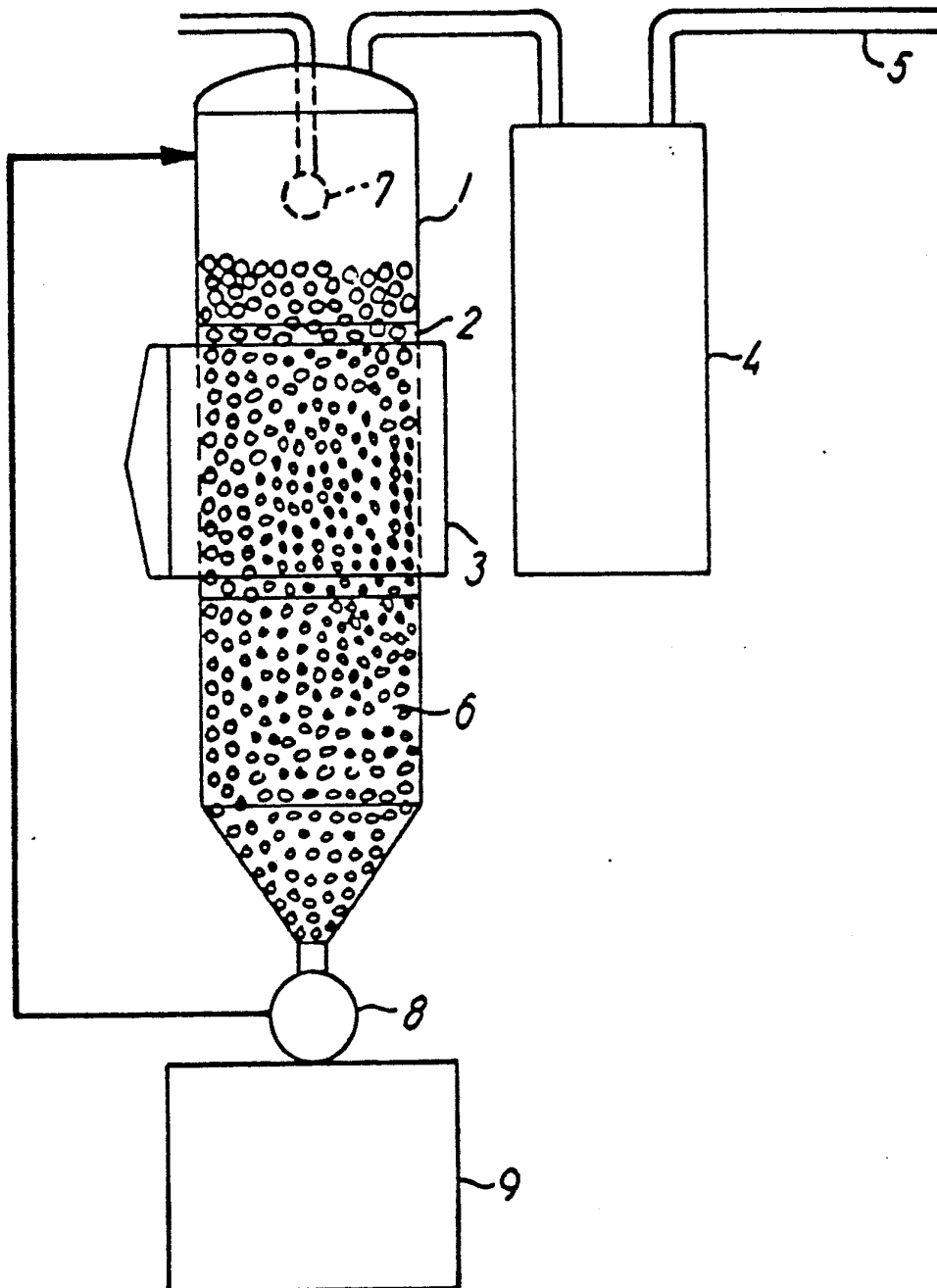
7. An apparatus as claimed in claim 5 or 6, characterized in having means in the container above the conveying means for distributing the liquid to be dried onto the conveying means in step with their being fed into the container.

8. A drying apparatus as claimed in claim 5, 6 or 7, characterized in that the members for discharging the conveying means from the bottom portion of the container and feeding them back into the top portion of the container is a system of worms known per se.

9. An apparatus as claimed in claim 8, characterized in that beneath the worm discharging conveying means and the powder obtained by the drying step it has a perforated plate or a sieve and therebeneath a vacuum-proof powder sluice known per se.

10. A drying apparatus as claimed in any of claims 5 to 9, characterized in that the zone of the cylindrical walls having a good penetrability to microwaves as well as the conveying means are produced from a polymeric organic material, preferably polycarbonate or teflon.

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INTERNATIONAL SEARCH REPORT

International Application No PCT/DK87/00032

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC 4		
F 26 B 3/347, 23/08		
II. FIELDS SEARCHED		
Minimum Documentation Searched 7		
Classification System	Classification Symbols	
IPC	B 01 J 19/08, /12; F 26 B 3/34, /347, 23/08	
US C1	34: 1	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
SE, NO, DK, FI classes as above		
III. DOCUMENTS CONSIDERED TO BE RELEVANT *		
Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No. 13
Y	DE, B, 2 058 774 (BASF AG) 9 March 1978 see column 2, lines 8 to 18	1,2,5
Y	GB, A, 593 806 (RADIO CORPORATION OF AMERICA) 27 October 1947	1,2,5
A	DE, C, 707 925 (SIEMENS-SCHUCKERTWERKE AG) 8 July 1941 see page 2, lines 114 to 120	1,5
A	US, A, 3 653 424 (CARLSSON) 4 April 1972	
A	US, A, 3 859 734 (WAHLGREN) 14 January 1975	
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IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
1987-06-12	1987-06-25	
International Searching Authority	Signature of Authorized Officer	
Swedish Patent Office	Björn Salén <i>Björn Salén</i>	