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(71) Applicant *(for all designated States except US)*: EN-WAVE CORPORATION [CA/CA]; 2000 - 1066 West Hastings Street, Vancouver, British Columbia V6E 3X2 (CA).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: DURANCE , Timothy D . [CA/CA]; 3491 West 38th Ave., Vancouver, British Columbia V6N 2X8 (CA). FU, Jun [CN/CA]; 1168 Riverside Dr ., Port Coquitlam, British Columbia V3B 8B3 (CA).

(74) Agents: MCGRUDER, David, J . et al.; Oyen Wiggs Green & Mutala LLP, 480 - The Station, 601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA).

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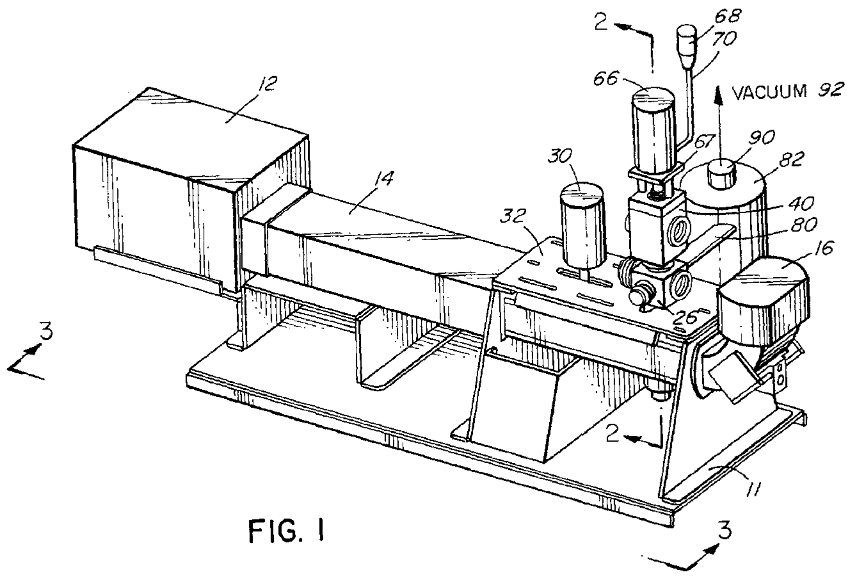

FIG. 1

(57) Abstract: An apparatus and method for microwave vacuum-drying of temperature- sensitive biological materials on a continuous flow-through basis, in which the materials are frozen, ground to frozen particles, dehydrated to a powder, and the powder collected. The apparatus (10) has a microwave generator (12) and waveguide (14), a freezing chamber (46) with a grinder (52), a rotatable dehydration chamber (18) in or adjacent to the waveguide, and a powder collector (82) to receive the powdered biological material. The apparatus operates under reduced pressure provided by a vacuum system (92) coupled to the powder collector (82).

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APPARATUS AND METHOD FOR DEHYDRATING BIOLOGICAL MATERIALS

Field of the Invention

The invention pertains to apparatuses and methods for microwave vacuum-drying of biological materials, in particular temperature-sensitive biological materials.

Background of the Invention

Many biologically-active materials, such as microbial cultures, proteins, enzymes, etc. are dehydrated for purposes of storage. Methods used in the prior art include freeze-drying and air-drying methods such as spray-drying. Dehydration generally lowers the viability of the materials. Freeze-drying allows higher viability levels than air-drying but it requires long processing times and is expensive.

It is also known in the art to dehydrate biological materials using microwave radiation in a vacuum chamber to remove water. When the materials are sensitive to damage at the elevated temperatures that can occur with microwaving, it is known to use a microwave freeze-drying process in which the material is frozen at low temperature in a vacuum chamber and the ice is sublimated by microwave radiation. Current systems are typically batch dehydrators, which limits efficiency. Also, current systems produce a dry "cake" from frozen solutions that must be subsequently milled to create a powder. Post-dehydration milling can produce excess heat and excess dust which can reduce biological activity and create handling difficulties, respectively.

Summary of the Invention

The invention provides an apparatus and method for dehydrating biological materials, employing freezing and microwaving. Examples of materials suitable for dehydration by means of the invention include bacterial suspensions, proteins, enzymes and other temperature-sensitive biological materials. Bacterial suspensions include many live-attenuated vaccines, dairy starter cultures, and other industrial starter cultures for fermentation processes. Proteins include milk proteins, egg proteins, soy proteins, and other plant and animal proteins, whether as isolates or in mixtures. Enzymes include proteases, trypsin, lysozyme, antibodies, immunoglobulins, amylases, cellulases, and other biological catalysts of industrial and medical importance. Other temperature-sensitive biological materials include deoxyribonucleic acid, ribonucleic acid, vegetable gums, antibiotics, and other complex organic molecules. Some plant extracts also benefit from freeze drying due to the presence of oxidation-susceptible components (e.g. ginseng extract) or unstable flavour components (e.g. coffee extract for soluble coffee, also known as instant coffee). The biological material, in an aqueous form such as a solution or suspension, is converted to frozen ice particles which are subjected to microwave vacuum-drying to form a powder, and the powder is conveyed to a collector.

The invention provides an apparatus for dehydrating an aqueous biological material having a microwave generator, a waveguide, and a freezing chamber for receiving the aqueous biological material and freezing it to form a frozen aqueous biological material. The apparatus includes means for feeding the aqueous biological material into the freezing chamber, means for forming a particulate frozen aqueous biological material from the frozen aqueous biological material, a dehydration chamber in fluid communication with the freezing chamber, and a powder collector in fluid communication with the dehydration chamber. A vacuum system is operatively connected to the powder collector for applying a vacuum to the freezing chamber, the dehydration chamber and the powder collector.

The invention further provides an apparatus for dehydrating an aqueous biological material having a microwave generator, a waveguide, and a freezing chamber for receiving and freezing the aqueous biological material. The apparatus includes means for feeding the aqueous biological material into the freezing chamber, a grinder in the freezing chamber, a rotatable dehydration chamber in fluid communication with the freezing chamber, and a powder collector in fluid communication with the dehydration chamber. Free-moving mill balls may be provided within the freezing chamber and/or the dehydration chamber. A vacuum system is operatively connected to the powder collector for applying a vacuum to the freezing chamber, the dehydration chamber and the powder collector.

The invention further provides a method for dehydrating an aqueous biological material. The aqueous biological material is fed into a freezing chamber. A particulate frozen material is formed from the aqueous biological material. The particulate frozen material is conveyed into a dehydration chamber and is microwaved under reduced pressure in the dehydration chamber to sublimate water from the material, producing a powdered biological material. The dried powder is conveyed from the dehydration chamber to a powder collector. The dehydration chamber may be rotated during the microwaving.

The invention further provides a method for dehydrating an aqueous biological material. The aqueous biological material is fed into a freezing chamber. The aqueous biological material is caused to freeze to a frozen material under reduced pressure in the freezing chamber. The frozen material is ground to a particulate frozen material. The particulate frozen material is conveyed into a rotatable dehydration chamber. The biological material may be further reduced in size by the grinding action of free-moving balls within the freezing chamber and/or the dehydration chamber. The dehydration chamber is rotated or oscillated and the particulate frozen material is microwaved under reduced pressure in the dehydration chamber to sublimate water from the material biological material. The powder is conveyed from the dehydration chamber to a powder collector.

These and other features of the invention will be apparent from the following description and drawings of the preferred embodiment.

Brief Description of Drawings

Figure 1 is an isometric view of an apparatus according to one embodiment of the invention.

Figure 2 is a cross-sectional view thereof on the line 2-2 of Figure 1.

Figure 3 is a schematic, cross-sectional view thereof on the line 3-3 of Figure 1.

Figure 4 is a sectional view of the freezing chamber.

Figures 5 and 6 are isometric, partly cutaway views of an apparatus according to a second embodiment of the invention.

Description of the Preferred Embodiments

First Embodiment of the Dehydrating Apparatus

Exemplary embodiments are illustrated in the drawings. The embodiments are to be considered illustrative rather than restrictive. In the following description and the drawings, like and corresponding elements are identified by the same reference numerals.

Referring to Figures 1 to 4, the dehydration apparatus **10** has a microwave generator **12**, a tubular waveguide **14** and a water load **16**, supported on a stand **11** and arranged so that microwave radiation from the generator travels through the waveguide and is absorbed by the water load.

A rotatable dehydration chamber **18** is located in the waveguide **14**. It has a microwave-transparent body comprising a cylindrical side wall **20**, an upper body portion **22** and a lower body portion **24**. A mounting block **26** is fitted into the upper wall **27** of the waveguide. The dehydration chamber is rotatably connected to the mounting block **26** with a rotatable sleeve **25** arranged vertically in the mounting block and attached to the dehydration chamber. A motor **30** is mounted on a support plate **32** above the waveguide upper wall **27**. A drivebelt **34** extends through a slot **36** in the mounting block from the pulley **38** of the motor **30** to engage the sleeve **25**. The sleeve **25** forms an annular channel **28** within the mounting block **26** for the transport of powder from the dehydration chamber. A rotatable shaft **29** with bearings is connected to the lower body portion **24** of the dehydration chamber to stabilize the rotation of the dehydration chamber. Optionally, the apparatus includes means for periodically reversing the direction of rotation of the dehydration chamber. This permits the chamber to oscillate.

A grinder housing **40**, best seen in the cutaway view of Fig. 4, is mounted on top of the mounting block **26**. It has a side wall **42**, a removable upper wall **44** and defines within it a freezing chamber **46**. An ice conduit **48** is attached to the bottom side **50** of the grinder housing, extending from the freezing chamber **46** through the mounting block **26** and sleeve **25** into the dehydration chamber **18**.

A grinder **52** is located in the freezing chamber **46**. It comprises a shaft **54** with two spaced blades **56** mounted thereon within a perforated grinder body **58** having a cylindrical side wall **60** and bottom wall **62**, both of which have a plurality of perforations **64**. A grinder motor **66** is mounted on a support plate **67**, which is supported by legs **69** on the grinder housing upper wall **44**. The grinder shaft **54** extends through a bore in the grinder housing upper wall and is connected to the grinder motor for rotation thereby.

Optionally, free-moving mill balls (not shown) may be provided within the freezing chamber, the dehydration chamber or both. In the dehydration chamber, the mill balls provide an action similar to that of a ball mill, assisting in forming fine powders. The action of the balls also keeps residues from building up in the dehydration chamber, thus eliminating potential fouling. In the freezing chamber **46**, within the grinder body **54**, free-moving mill balls assist in size-reduction of the frozen material and also prevent fouling. The mill balls in the dehydration chamber may be made of ceramic, quartz or other hard material with a sufficiently low dielectric loss factor so as not to heat in the microwave field.

A feedstock supply vessel **68** for the aqueous biological material to be processed is connected by a conduit **70** to an inlet port **72** in the upper wall **44** of the grinder housing, whereby the feedstock is fed into the freezing chamber **46**. A feedstock flow controller **74** is connected to the inlet **72** for regulation of the rate of flow of the feedstock.

The mounting block **26** defines a chamber **76** which is open from its lower side to the annular channel **28**. The ice conduit **48** extends through this chamber **76** and through the sleeve **25**. The chamber **76** is open on one side through a powder outlet port **78**. A powder outlet conduit **80** connects the outlet port **78** of the chamber **76** to a powder collector **82**. This collector comprises a closed vessel having a cylindrical side wall **84**, a bottom wall **86** and a lid **88**. Powder is removed from the powder collector by gravity, that is, by falling through the powder collector outlet **94** into a reservoir chamber or chambers (not shown). Powder may be directed to alternate reservoirs by a selector valve to allow periodic emptying of the reservoirs. The powder outlet conduit **80** extends into the powder collector through its side wall. A vacuum inlet tube **90** extends through the lid **88** into the powder collector and is connected to a vacuum pump **92**, or other vacuum source, and a water condenser (not shown).

The freezing chamber **46**, dehydration chamber **18**, powder collector **82** and the passageways that connect them form a closed system, and accordingly the application of vacuum to the vacuum inlet tube **90** creates a low pressure state throughout the system. Typical operating pressures are in the range of 0.1 to 1.0 mm of mercury absolute pressure.

The apparatus **10** also includes a controller (not shown) such as a PLC (programmable logic computer) to operate the system, including controlling the inflow of feedstock, the microwave output, the vacuum system, and the rotation of the grinder and the dehydration chamber.

The dehydrating apparatus **10** operates according to the following method. First, the aqueous biological material feedstock is prepared and loaded in the feedstock supply vessel **68**. For example, the feedstock solution may be pre-concentrated by vacuum evaporation to a viscous liquid. Bacterial cultures or other liquid suspensions may be propagated in a fermentation vessel, then concentrated by centrifugation to approximately 20% solids. The vacuum pump **92**, the microwave generator **12**, the grinder motor **66** and the dehydration chamber motor **30** are actuated. The aqueous biological material is fed into the freezing chamber **46**. The material immediately freezes to ice under the reduced pressure. The grinder grinds the frozen material to ice particles, which pass through the perforations **64** in the grinder body **58** and descend through the ice conduit **48** into the spinning dehydration chamber **18**. The microwave radiation passing through the waveguide sublimates the ice to water vapor, leaving the biological material in the chamber **18** as a dry powder. Optionally, free-moving mill balls in the freezing chamber and/or the dehydration chamber assist in forming fine powder. As water vapor from the sublimated ice is drawn toward the vacuum inlet tube **90**, the powder is drawn with it through the annular powder channel **28**, the chamber **76** and the powder outlet conduit **80**, and is deposited into the powder collector **82**. The water vapor exits the powder collector through the vacuum inlet tube **90**. The vacuum system delivers the water vapor to the condenser to be condensed and frozen to ice.

The system operates on a continuous throughput basis, with collected powder being removed periodically from the powder collector.

Second Embodiment of the Dehydrating Apparatus

In the dehydration apparatus **10** described above, the grinder shaft **54** and the dehydration chamber **18** are rotatable about an axis that is substantially vertical. The invention includes dehydrating apparatuses in which this axis of rotation is not vertical. For example, it may be horizontal or have a slope.

Figures 5 and 6 illustrate a dehydration apparatus **100** in which this axis of rotation is substantially horizontal. The dehydration apparatus **100** comprises three dehydration units **102, 104, 106** arranged in series. The first dehydration unit **102**, shown in detail in cutaway view in Fig. 6, has a housing **108** with an input end **110** and an output end **112**. A microwave-transparent tube **114** extends longitudinally through the unit and is rotatable about its longitudinal axis by a motor **116**. The tube **114** defines a dehydration chamber **115**.

A freezing chamber **46** with a grinder **52** for grinding ice is provided at the input end **110** of the tube **114**. The grinder has grinder blades **56** rotatable within a grinder body **58** by a grinder motor **66**.

The dehydration apparatus **100** has a feedstock supply system (not shown) which is the same as that described above for the dehydration apparatus **10**, namely a feedstock supply vessel, feedstock flow controller and an inlet conduit, for delivering aqueous biological material to an inlet port **72** of the freezing chamber **46**.

An auger **118**, rotatable by a motor **120** in an auger tube **122** is positioned under the freezing chamber **46** to receive ice particles from the grinder and feed them into the input end of the dehydration chamber **115**. Optionally, the freezing chamber **46** or the dehydration chamber **115**, or both, may be provided with free-moving mill balls **125**.

The dehydration unit **102** includes a set of microwave generators **12**, five in the illustrated embodiment, connected to waveguides **126** which extend circumferentially around the tube **114** between the housing **108** and the tube **114**. The waveguides **126** are separated by circumferential spaces **124**. Water circulation tubes **128** extend longitudinally through the space between the housing **108** and the tube **114**, passing through the waveguides **126**. A pump (not shown) pumps water through the water tubes **128**. The water acts as a water load for absorbing energy and carrying away heat.

The dehydration chamber **115** is open at the outlet end **112** of the dehydration unit **102**, with an outlet conduit portion **130** of the tube extending into a powder collector **132**. The conduit portion **130** has a lip

134 at its inward end which prevents the mill balls from entering the powder collector. Alternatively, a screen can be provided for this purpose at the inward end of the conduit portion **130**. A vacuum inlet tube **90** extends through the lid **88** of the powder collector **132** and is connected to a vacuum source and water condenser (not shown). A powder outlet conduit **136** extends from the powder collector outlet **94** on the bottom side of the powder collector **132**. At its lower end, the conduit **136** is open to the auger **118A** of the second dehydration unit **104**.

The second dehydration unit **104** and the third dehydration unit **106** have the same structure as the first unit **102**. They feed powder into powder collectors **132A** and **132B** respectively, which have vacuum inlet tubes **90A** and **90B** respectively, connected to the vacuum source and water condenser. Powder produced by the first unit **102** is fed into the second unit **104** by the auger **118A**, rotated by a motor **120A**. The powder that exits the second unit **104** enters the second powder collector **132A** and is delivered by an auger **118B** to the third dehydration unit **106**. The powder that exits the third unit **106** enters the third powder collector **132B**. A chute extends from the bottom side of the powder collector **132B** to the powder receptacles **140**. A selector valve **142** between the chute **138** and the receptacles allows for the periodic removal and emptying of the receptacles **140**.

The apparatus **100** also includes a controller (not shown), such as a PLC, to operate the system.

The dehydrating apparatus **100** has been described and illustrated as comprising three dehydration units in series. However, it can comprise any selected number, for example one, two, or four or more. This is a matter of design choice, dependent upon the desired dehydration capacity, final moisture content, type of biological material and particle size. For example, larger particles may require longer microwave exposure at a lower power to achieve the same final moisture content, while hydroscopic compounds such as simple sugars may require longer microwave exposure than less hydroscopic compounds such as large molecular weight polysaccharides.

The dehydrating apparatus **100** operates according to the following method. The vacuum pump, water pump, microwave generators **12**, grinder motor **66**, three auger motors **120**, **120A**, **120B**, and the dehydration chamber motors **116**, **116A**, **116B** are actuated. The dehydration chamber motors **116**, **116A**, **116B** may be operated at different rotation speeds, and the respective sets of microwave generators **12** of each of the units **102**, **104**, **106** may be operated at different power levels. For example, the microwave power level may be highest in the first unit **102**, lowest in the third unit **106** and intermediate in the second unit **104**. The dehydration chamber rotation speed may be highest in the first unit **102**, lowest in the third unit **106** and intermediate in the second unit **104**. The settings are selected to optimize the drying of the powder, the object being to obtain fully dried powder in the receptacles **140** after processing in all three units.

The aqueous biological material is fed into the freezing chamber **46**. The material immediately freezes to ice under the reduced pressure. The grinder grinds the frozen material to ice particles, which pass through the perforations in the grinder body **58** and fall into the auger tube **122**. The auger **118** moves the particles into the rotating dehydration chamber **115**. Microwave radiation passing through the waveguides **126** passes through the microwave-transparent tube **114** and sublimates the ice to water vapor, leaving partially dried, powdered biological material in the chamber. Optionally, there are free-moving mill balls in the freezing chamber and/or the dehydration chamber which assist in forming fine powder.

As water vapor is drawn toward the vacuum inlet tube **90**, the powder is drawn with it through the chamber **115**, outlet conduit **130** and into the powder collector **132**. To assist the movement of powder through the chamber **115**, vanes may optionally be provided on the inner wall of the tube **114**, or the dehydration unit may optionally be sloped downward from the input end to the output end, whereby movement of the powder toward the outlet end is assisted by gravity.

From the powder collector **132**, the powder descends through the conduit **136** to the auger **118A** of the second unit **104**. The drying process continues in the same manner in the second and third units **104**, **106**, delivering fully dried powder to the powder receptacles **140**. When one receptacle **140** is full, the selector valve **142** directs powder to an empty receptacle, and the filled receptacle is removed. The system is operated on a continuous throughput basis.

Example

A dehydration apparatus in the form of the apparatus **10** described above has a microwave generator with a power output of 500 watts. The vacuum system evacuated the apparatus to an absolute pressure of 0.20 mm of mercury. The dehydration chamber was rotated at 300 rpm and the grinder at 100 rpm. A 20% solution by weight of chicken lysozyme in water was applied as the feedstock at a rate of 0.4 mL per minute. The apparatus was operated according to the method described above, producing outlet powder with a moisture content of 4.53%. Lysozyme activity retention was almost entirely retained in the dried product.

Although the invention has been described in terms of particular embodiments, it is not intended that the invention be limited to these embodiments. Various modifications within the scope of the invention will be apparent to those skilled in the art. For example, instead of spinning the dehydration chamber, an impeller or other form of agitator may be provided in the chamber to induce the flow of dehydrated powder therefrom. Further, instead of forming ice particles by means of grinding, a spraying or atomizing system can be employed to form droplets of the feedstock which freeze to ice particles and do not require grinding to be in a suitable form to flow into the dehydration chamber and be microwaved. The scope of the invention is defined by the claims that follow.

List of Reference Numerals in the Drawings

10 dehydration apparatus
11 stand
12 microwave generator
14 waveguide
16 water load
18 dehydration chamber
20 side wall of dehydration chamber
22 upper body portion of dehydration chamber
24 lower body portion of dehydration chamber
25 rotatable sleeve
26 mounting block
27 upper wall of waveguide
28 annular powder channel
29 shaft with bearings
30 motor for dehydration chamber
32 support plate
34 drivebelt
36 pulley slot in mounting block
38 motor pulley
40 grinder housing
42 side wall of grinder housing
44 upper wall of grinder housing
46 freezing chamber
48 ice conduit
50 bottom side of grinder housing
52 grinder
54 grinder shaft
56 grinder blades
58 grinder body

60 side wall of grinder body
62 bottom wall of grinder body
64 perforations in grinder body
66 grinder motor
67 support plate
68 feedstock supply vessel
69 support legs
70 feedstock conduit
72 feedstock inlet port
74 feedstock flow controller
76 chamber in mounting block
78 outlet port in mounting block
80 powder outlet conduit
82 powder collector
84 powder collector side wall
86 powder collector bottom wall
88 powder collector lid
90, 90A, 90B vacuum inlet tubes
92 vacuum pump
94 powder collector outlet
100 dehydration apparatus
102 first dehydration unit
104 second dehydration unit
106 third dehydration unit
108 housing of dehydration unit
110 input end of dehydration unit
112 output end of dehydration unit
114 rotatable tube
115 dehydration chamber
116, 116A, 116B motors for dehydration chambers
118, 118A, 118B augers

120, 120A, 120B auger motors

122 auger tube

124 space between waveguides

125 mill balls

126 waveguides

128 water circulation tubes

130 outlet conduit of dehydration chamber

132, 132A, 132B powder collectors

134 lip of outlet conduit

136 powder outlet conduit

138 powder chute

140 powder receptacles

142 selector valve

WHAT IS CLAIMED IS:

1. An apparatus for dehydrating an aqueous biological material, comprising:

(a) a microwave generator;

(b) a waveguide to direct microwave radiation from the generator;

(c) a freezing chamber for receiving the aqueous biological material and freezing it to form a frozen aqueous biological material;

(d) means for feeding the aqueous biological material into the freezing chamber;

(e) means for forming a particulate frozen aqueous biological material from the frozen aqueous biological material;

(f) a dehydration chamber in fluid communication with the freezing chamber, the chamber being capable of receiving microwave radiation produced by the generator;

(g) a powder collector in fluid communication with the dehydration chamber; and

(h) means for operatively connecting a vacuum system to the powder collector for applying a vacuum to the freezing chamber, the dehydration chamber and the powder collector.

2. An apparatus according to claim 1, wherein the dehydration chamber is rotatable and the apparatus includes means for rotating the dehydration chamber.

3. An apparatus according to claim 2, further comprising means for periodically reversing the direction of rotation of the dehydration chamber such that the dehydration chamber oscillates.

4. An apparatus according to any preceding claim, wherein the dehydration chamber is positioned in the waveguide.

5. An apparatus according to any preceding claim, further comprising an agitator in the dehydration chamber.

6. An apparatus according to any preceding claim, wherein the dehydration chamber has a wall that is transparent to microwave radiation.

7. An apparatus according to any preceding claim, further comprising free-moving mill balls in the dehydration chamber.

8. An apparatus according to any preceding claim, wherein the means for forming a particulate frozen aqueous biological material comprises a grinder.

9. An apparatus according to any one of claims 1 to 3, wherein the means for forming a particulate frozen aqueous biological material comprises a sprayer.

10. An apparatus according to any preceding claim, wherein the means for forming a particulate frozen aqueous biological material is positioned within the freezing chamber.

11. An apparatus according to any preceding claim, further comprising free-moving mill balls in the freezing chamber.

12. An apparatus according to any preceding claim, further comprising the vacuum system.

13. An apparatus according to any preceding claim, further comprising a second dehydration chamber having an inlet end operatively connected to the powder collector, and having a second powder collector at an outlet end of the second dehydration chamber.

14. An apparatus according to claim 13, wherein the dehydration chambers comprise tubes oriented substantially horizontally.

15. An apparatus according to claim 13 or 14, further means for operatively connecting the vacuum system to the second powder collector.

16. An apparatus according to claim 13, 14 or 15, further comprising a third dehydration chamber having an inlet end operatively connected to the second powder collector, and having a third powder collector at an outlet end of the third dehydration chamber.

17. An apparatus according to any preceding claim, wherein the aqueous biological material comprises a bacterial suspension, a protein, an enzyme, deoxyribonucleic acid, ribonucleic acid, a vegetable gum, or an antibiotic.

18. A method for dehydrating an aqueous biological material, comprising the steps of:

(a) feeding the aqueous biological material into a freezing chamber;

(b) forming a particulate frozen material from the aqueous biological material;

(c) conveying the particulate frozen material into a dehydration chamber;

(d) microwaving the particulate frozen material under reduced pressure in the dehydration chamber to sublimate water from the material, to produce a powdered biological material; and

(e) conveying the powder from the dehydration chamber to a powder collector.

19. A method according to claim 18, wherein the step of forming the particulate frozen material comprises freezing the aqueous biological material and grinding the frozen material.

20. A method according to claim 18 or 19, further comprising the step of rotating the dehydration chamber during the microwaving.

21. A method according to claim 18, 19 or 20, further comprising the step of agitating the powder in the dehydration chamber.

22. A method according to claim any one of claims 18 to 21, wherein the step of conveying the powder is done by applying a vacuum to the powder collector.

23. A method according to any one of claims 18 to 22, wherein the step of forming a particulate frozen material is done under reduced pressure.

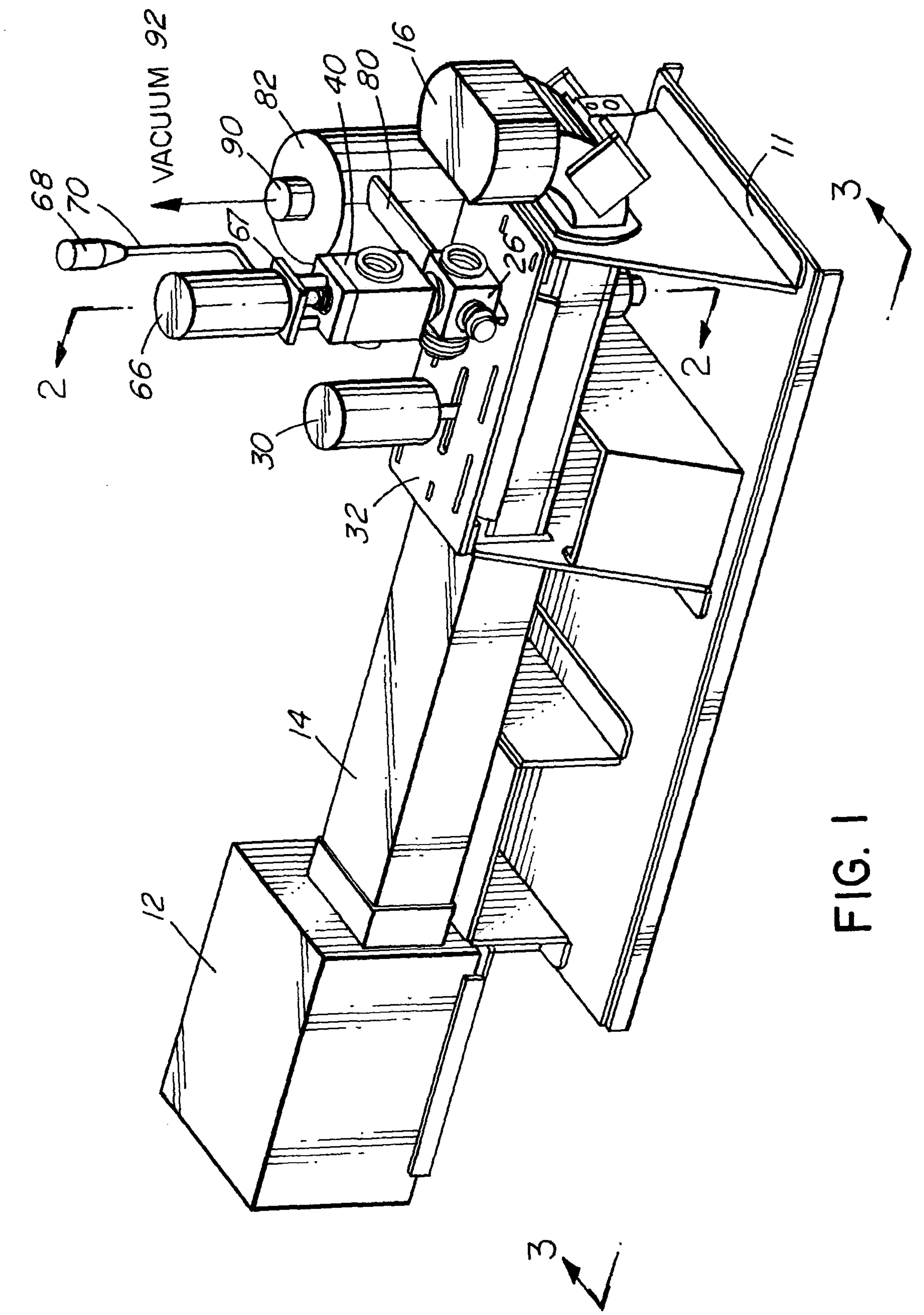

FIG. 1

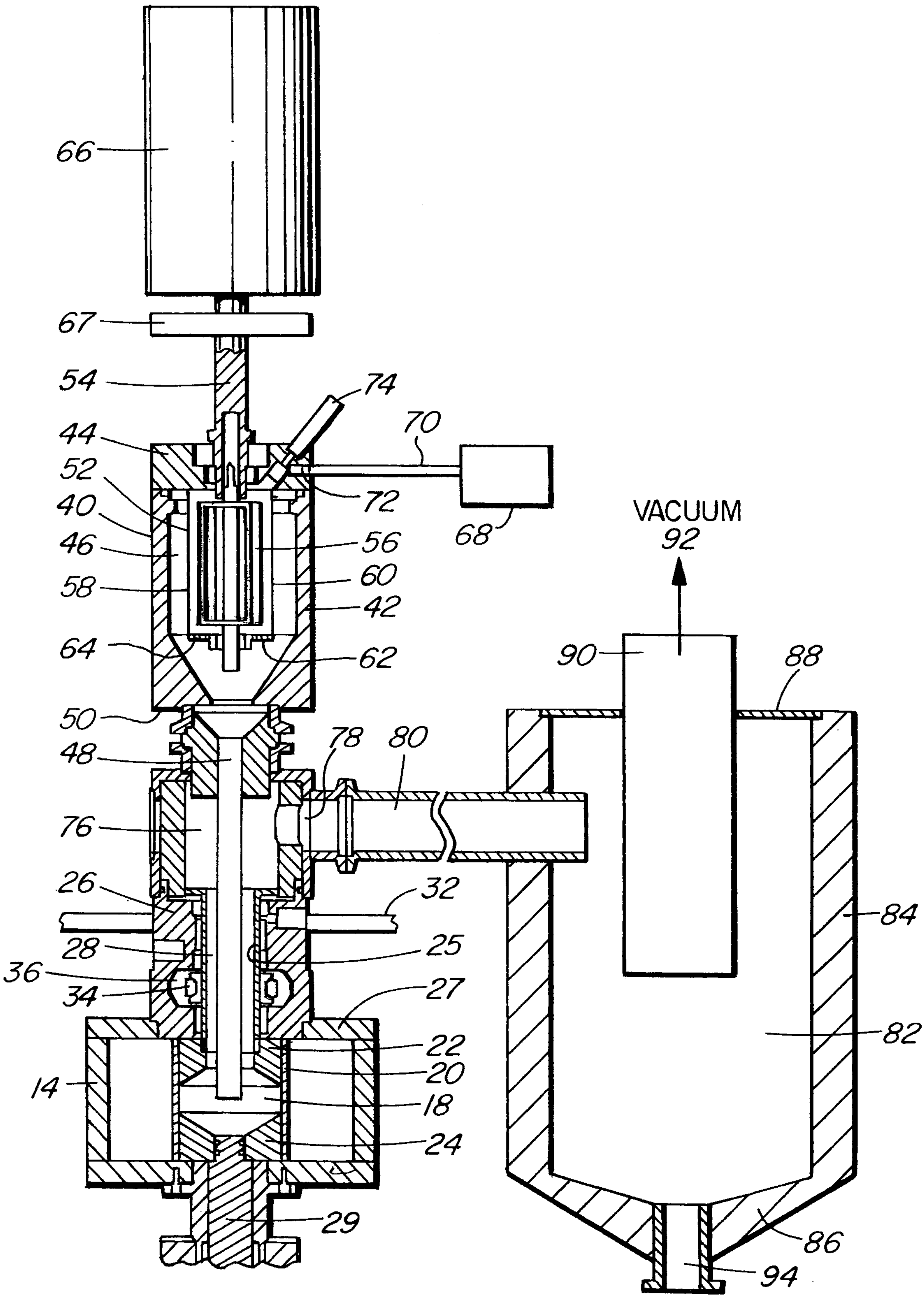
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FIG. 2

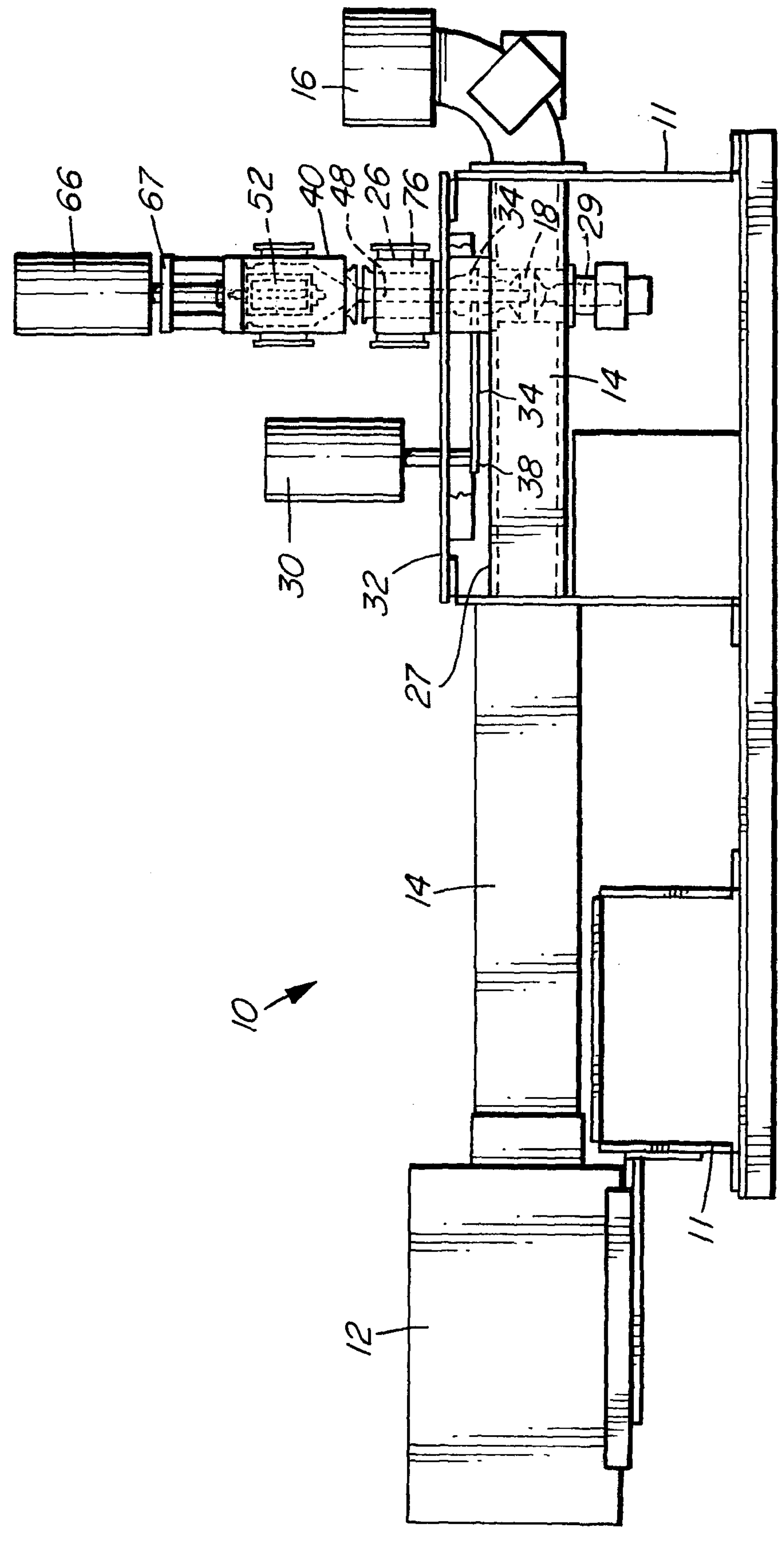


FIG. 3

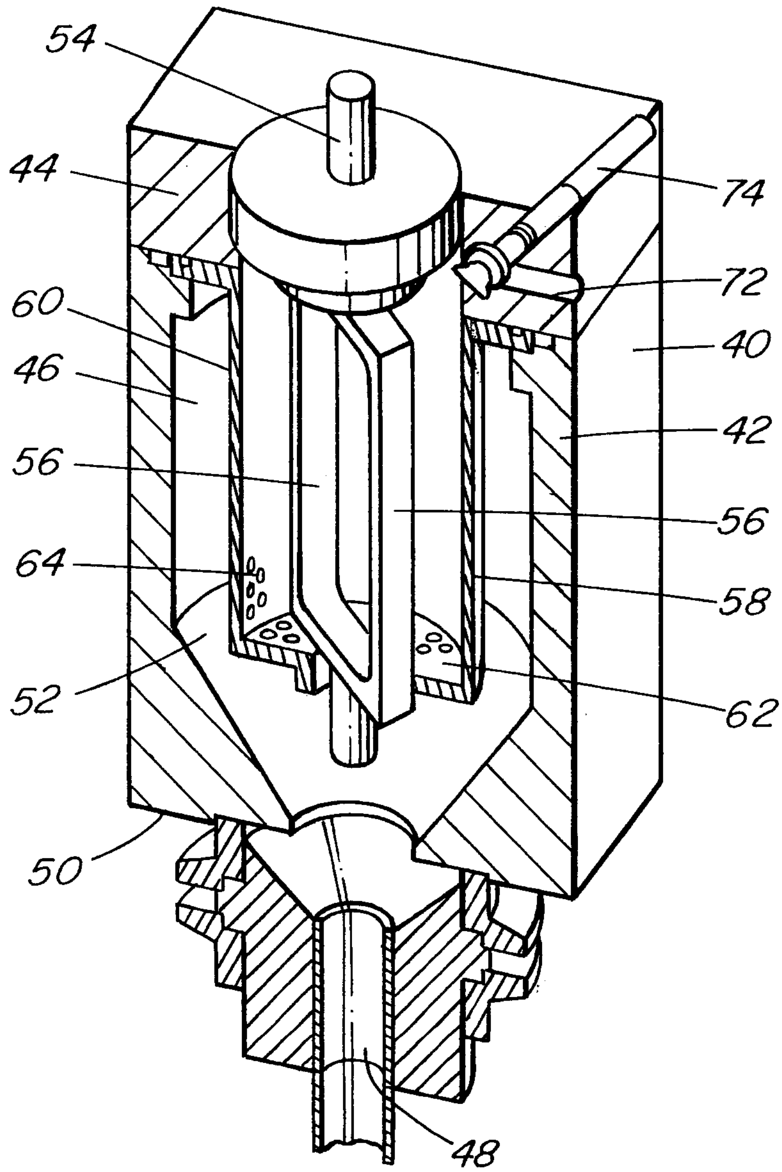
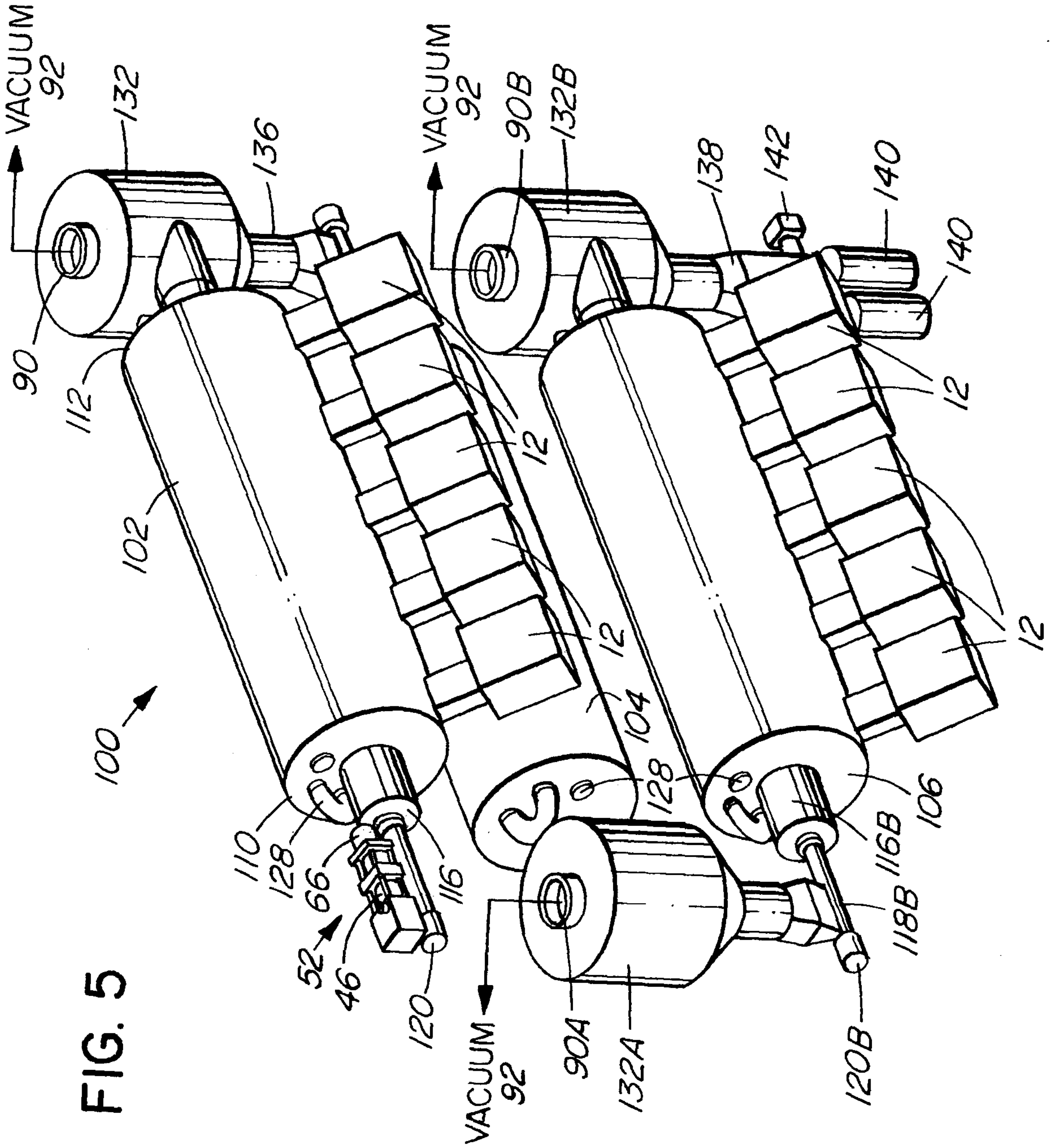


FIG. 4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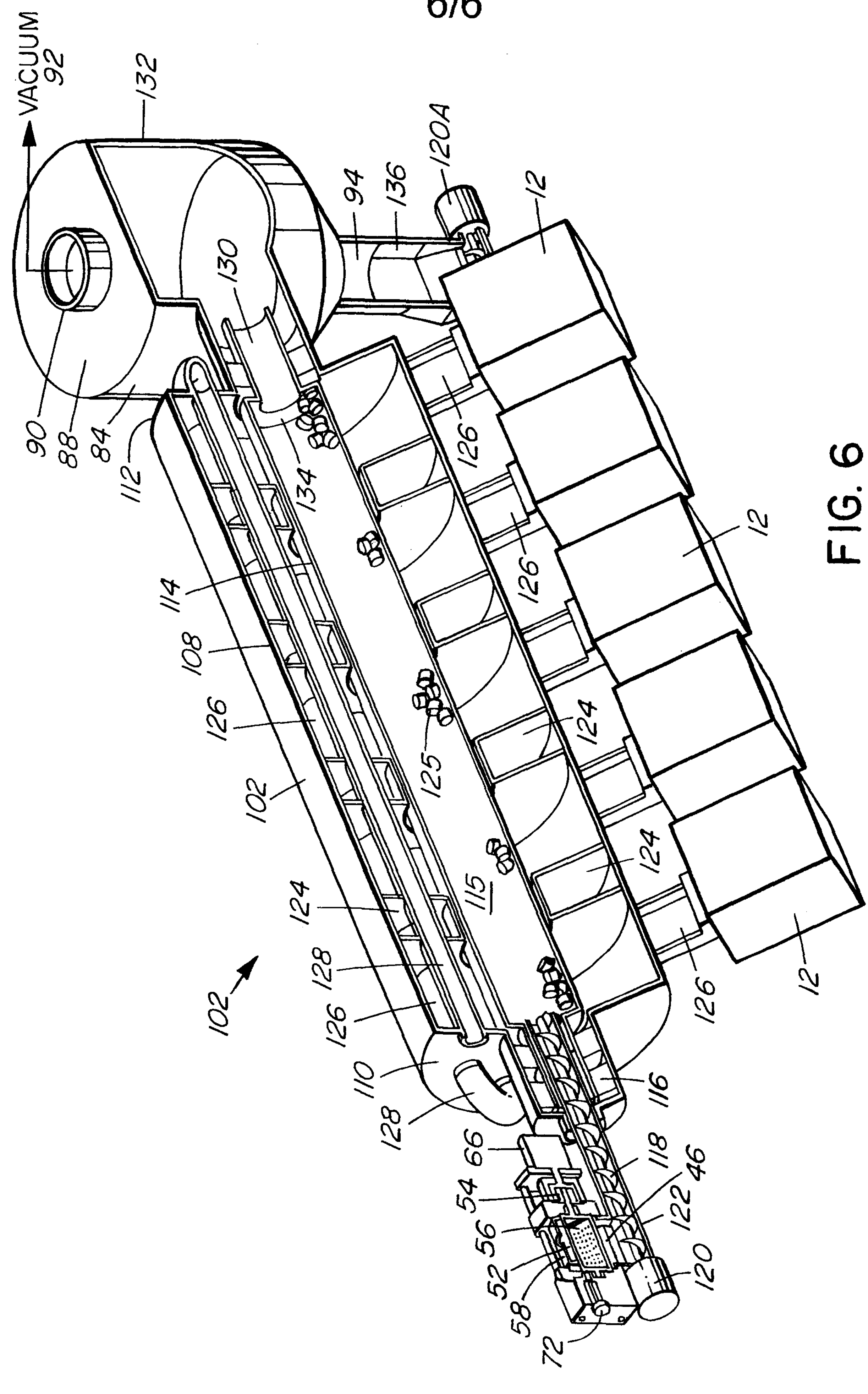
116B
118B
120B
132A
90A
VACUUM
92

FIG. 5


VACUUM
92
132
120A
136
94
12
130
90
88
84
112
134
126
114
108
126
125
124
102
124
115
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120
72

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2010/000629

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***C12M 1/42*** (2006.01) , ***B01J 19/12*** (2006.01) , ***C07K 1/00*** (2006.01) , ***C12M 1/00*** (2006.01) , ***C12N 1/04*** (2006.01) , ***C12N 13/00*** (2006.01) (more IPCs on the last page)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C12M 1/42 (2006.01) , ***B01J 19/12*** (2006.01) , ***C07K 1/00*** (2006.01) , ***C12M 1/00*** (2006.01) , ***C12N 1/04*** (2006.01) , ***C12N 13/00*** (2006.01), ***C12N 9/98*** (2006.01) , ***F26B 3/347*** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patent Database, TotalPatent and PubMed
Inventor: Durance, Timothy D. and Keywords: Vacuum, microwave, lyophilization, dehydration and freezing chamber

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO2005/105253 A1 (CARSON, J.K. ET AL.) 10 November 2005 (10-11-2005) *see entire document*	1, 4-6, 8-10, 12-19 and 21-23
Y		2, 3 and 20
Y	WO2009/049409A1 (DURANCE, T.D. ET AL.) 23 April 2009 (23-04-2009) *see entire document*	2, 3 and 20
A	WOJDYŁO, A. ET AL. "Effect of Drying Methods with the Application of Vacuum Microwaves on the Bioactive Compounds, Color, and Antioxidant Activity of Strawberry Fruits." Journal of Agricultural and Food Chemistry. Web publication date 26 January 2009 (26-01-2009), Vol. 57, pages 1337-1343, ISSN 0021 8561 * see "Materials and Methods" section on page 1338*	1-23
A	WO2009/033285 A1 (DURANCE, T.D. ET AL.) 19 March 2009 (19-03-2009) *see entire document*	1-23
A	WO2005/073652 A2 (SHAHAM, G.) 11 August 2005 (11-08-2005) *see entire document*	1-23

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2010 (27-07-2010)	10 August 2010 (10-08-2010)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Stephanie Etchells (819) 953-7568

C12N 9/98 (2006.01) , ***F26B 3/347*** (2006.01)

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
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		AU2005237933B2	28 May 2009 (28-05-2009)
		BRPI0510529A	30 October 2007 (30-10-2007)
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		CN1956758A	02 May 2007 (02-05-2007)
		EP1742716A1	17 January 2007 (17-01-2007)
		EP1742716A4	25 February 2009 (25-02-2009)
		JP2007535652T	06 December 2007 (06-12-2007)
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		MXPA06012614A	18 July 2007 (18-07-2007)
		NZ529594A	26 January 2007 (26-01-2007)
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		ZA200609631A	27 December 2007 (27-12-2007)
WO2009049409A1	23-04-2009	AU2008314458A1	23 April 2009 (23-04-2009)
		AU2008314458A2	10 June 2010 (10-06-2010)
		CA2678089A1	23 April 2009 (23-04-2009)
		EP2200458A1	30 June 2010 (30-06-2010)