(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 June 2007 (21.06.2007)

PCT

(10) International Publication Number
WO 2007/068248 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/DK2006/000708

(22) International Filing Date:
12 December 2006 (12.12.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA 2005 01758 12 December 2005 (12.12.2005) DK

(71) Applicant *(for all designated States except US)*: **MANUROX APS** [DK/DK]; Magnoliavej 5, DK-4000 Roskilde (DK).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **THOMSEN, Anne Belinda** [DK/DK]; Magnoliavej 5, DK-4000 Roskilde (DK). **GOUL, Søren** [DK/DK]; Gærupvej 11, Gærup, DK-7752 Snedsted (DK).

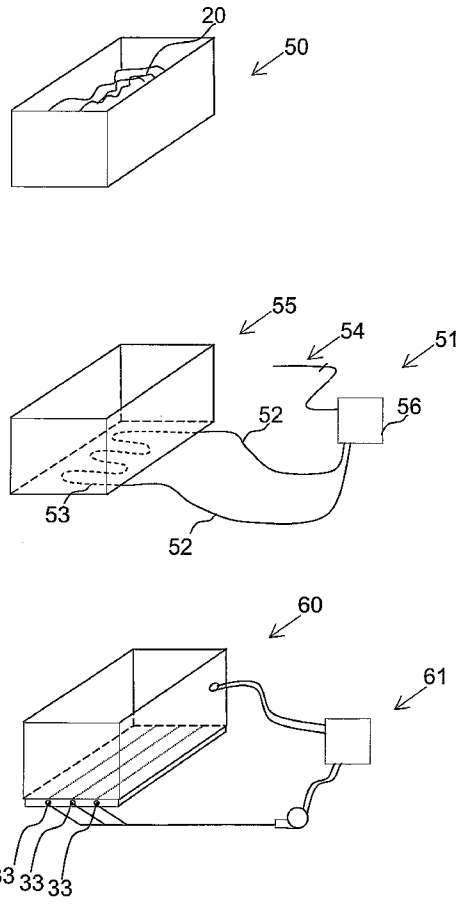
(74) Agent: **PATRADE A/S**; Fredens Torv 3A, DK-8000 Aarhus C (DK).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

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(54) Title: METHOD AND FACILITY FOR MANUFACTURING A NATURAL FERTILIZER



(57) Abstract: The object of the present invention is to create a biological composting method for the manufacture of a natural fertilizer, enriched soil or the like, in which process the pH value is lowered in a natural way, and where manure or residue from a biogas installation is used as a major component in the natural fertilizer product. The biological composting method provides a product in which the ammonia content is maintained, malodorous substances are converted, and vital nutrients both micronutrients and, in particular, macronutrient are conserved such that a substantial odour free and a stable natural fertilizer product is obtained.

WO 2007/068248 A2

FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method and facility for manufacturing a natural fertilizer

Field of the Invention

The present invention relates to a method for the manufacture of a natural fertilizer, enriched soil or the like. Furthermore, the invention is also directed to a facility suitable for the manufacture of such a natural fertilizer, enriched soil or the like.

The object of the present invention is, therefore, to create a biological composting method for the manufacture of a natural fertilizer, enriched soil or the like, in which process the pH value is lowered in a natural way, and where manure or residue from a biogas installation is used as a major component in the natural fertilizer product. The biological composting method provides a product in which the ammonia content is maintained, malodorous substances are converted, and vital nutrients both micronutrients and, in particular, macronutrient are conserved such that a substantial odour free and a stable natural fertilizer product is obtained.

Prior Art

It has for a rather long time been a problem in agriculture, and in particular for animal production, to use the manure on the fields in that there are a number of problems associated with spreading the manure on the fields from which one is the environmental concern which dictates that it may only be spread on the fields during certain seasons. The spreading of manure has to take place at certain times during the year, where the leading of nutrients from the manure to the aquatic environment may be minimized.

The urban spread has also created problems for agriculture in that people living in these new urban areas will suffer odour problems in the periods where the manure is spread in the fields, and during a period of time until the malodorous substances have either been converted by natural processes into soil, or have evaporated. Every farmer feels that his livelihood is threatened when he repeatedly is being reported to the local authorities for nuisance in connection with distribution of manure in the fields. Even when limiting the distribution to the limited periods during the year where spreading of manure is allowed, it still causes annoyance for people living in the vicinity.

The nuisances deriving from the odour of the manure spreading process is in particularly caused by the ammonia evaporation from the manure when it is being spread. Ammonia is soluble in water, but is at the same time convertible to a gas, which will evaporate at ambient temperature ($NH_3(Aq.) \leftrightarrow NH_3(gas)$), especially at pH values above 7.

In the soil, an equilibrium will be established between the ammonia and ammonium which will be further converted to nitrate. Both ammonium and nitrate will be used by plants for growth. Part of the nitrate will be converted into dinitrogene oxide, also known as laughing gas (N_2O), which will evaporate and dispense in the atmosphere. Dinitrogene oxide is a so-called *green house gas*, and it is environmentally desirable to limit the emission of these green house gasses.

When the manure is spread during fall, the low temperature will reduce the evaporation, but a substantial part of the manure, in particular the liquid fraction, will evaporate before it is converted in the soil.

On the other hand, it is important for the quality and condition of the soil to recirculate as much manure and other similar residual products from agriculture as possible in the soil in order to maintain, and possibly improve, the fertility of the soil. The soil has, furthermore, use for organic material and nutrient in order to maintain the biological activity which is a characterising feature of a fertile soil. The plants growing in the soil need both micro and macro nutrients in order to grow, and in order to be able to build up a substantial amount of vital nutrients such as vitamins, plant enzymes and minerals, in order to build up resistance against plant diseases. If this may be achieved in an environmental-friendly manner, the use of pesticides may be reduced.

During the last thirty years, the outcome has increased more than 30% per hectare due to more intensive farming methods. This means that the soil in many places has been depleted of vital nutrients. This in turn causes the conventional farmer to use huge quantities of fertilizer, and in particular artificial fertilizers where the main constituents are nitrogen, potassimum and phosphor. Potassium and ammonia are positively loaded ions (K^+ and NH_4^+) will in large amounts replace and displace other positively loaded ions such as for example Zn, Cu, Mn, Co, Mo, which otherwise have a deci-

sively positive influence on the ability of the plants to synthesize especially vitamins and enzymes.

Furthermore, there is a general depletion of the micro nutrition element selenium (Se) in Northern Europe, and in particular in Denmark. The influence of selenium on the synthesizing processes of vitamins and enzymes is not known in detail, but selenium is easily obtained and used by plants, and there is a consensus that selenium has a decisive influence on the well-being of animals and humans, and in particular in order to improve the resistance against certain cancer types, cardiovascular diseases as well as allergies.

The efficient cleansing of Sulphur from waste gasses, in particular form energy production, has brought about less pollution overall, but in particular in Northern Europe the Sulphur content in the soil has been depleted, and the soil indicates a lack of Sulphur which is essential for the growth of plants. Sulphur is just as nitrogen, potassium, phosphor and magnesium a macro nutrient. Sulphur plays a part in the synthesis of proteins which are of major importance for the growth of plants. Another important reason why this lack of certain vital micro and macro nutrients has occurred is the fact that it is no longer allowable to burn straw left in the fields. Straw contains large amounts of inorganic salts, in certain areas, depending on the crops up to 10-15%. By burning the straw on the field, these vital salts are returned to the soil, but due to the systematic removal of the straw from the fields, the important minerals and salts are also removed whereby the soil over time is depleted of these important minerals, which again in turn provide the plants with less resistance against diseases in that the important enzyme and vitamin synthesis does not occur.

The result is the fact that the quality of the plants decreases which means that the animals and humans living of these plants become less resistant to diseases, and a vicious circle has begun.

The general health of both animals and humans has deteriorated at an alarming level in the latter years. In Denmark, for example, the rate of certain cancer types as well as cardiovascular diseases is among the highest of the world, but also the occurrence of asthma and eczemas is more widespread than ever before. Horse people and farmers

have noticed a substantial amount of diseases among the animals in comparison to what was present twenty-five years ago. These facts indicate that there may be a connection between the way we grow our crops and certain serious illnesses which every year burden society by several million Danish kroner.

Object of the Invention

Consequently, it is an object of the present invention to manufacture a natural fertilizer or enriched soil where the product has substantially no malodour and a significant reduced evaporation/loss of ammonia to the atmosphere. The fertilizer is rich on essential micro and macro nutrients, and has a large content of organic matter for the benefit of bacteria and microbes.

The invention describes a method for the manufacture of such a natural fertilizer, enriched soil or the like which is based on composting manure or solid fractions of manure with an added content of lignocellulosic material.

The manure may be any type of manure, for example obtained from pigs, cattle, horses, sheep, chickens or any other animal.

The lignocellulosic material may be obtained from a number of sources. The most readily available source is straw, which may be straw in its broadest sense, i.e. straw from wheat, oat, barley, rice, corn, rape seed, grass or any other crop. The lignocelluloses material may, further, be a waste residue of straw utilisation such as horse bedding material or deep litter etc.. The lignocellulosic material may, further, be in the shape of hulls. Within the context of the present invention, so-called hulls generally denotes the outer covering, rind, shell, pod or husk of any plant. The term employed herein also embraces for example, the outer covering of an ear of maize. Relevant hulls include hulls selected among the following:

hulls from grasses, oat *(Avena spp., such* as A. *sativa),* barley *(Hordeum spp.,* such as H. *vulgare),* wheat *(Triticum spp.,* including T. *durum);* rye *(Secal cereale),* rice *(Oryza* spp.), millet (e.g. species of *Digitaria, Panicum, Paspalum, Pennisetum or Setaria),* sorghum *[Sorghum spp.,* including S. *bicolor* var. *durra* (known, *inter alia,* as "durra") and milo], buckwheat *(Fagopyrum spp.,* such as F. *esculentum),* maize [also

known as corn *(Zea mays),* including sweetcorn], corn cob, rape-seed (from *Brassica spp.,* such as B. *napus, B. napus subsp. rapifera or B. napus* subsp. *oleifera),* cotton-seed (from Gossypium spp., such as G. *heraceum),* almond (Prunus dulcis, including both sweet and bitter almond) and sunflower seed *(Helianthus spp.,* such as *H. annuus).*

Description of the Invention

The invention therefore provides a method which is particular in that the method comprises the following steps:

a) a mixture is created by mixing manure with one or more types of lignocellulosic material such that the ratio of lignocellulosic material to the solid fraction of the mixture is in the range from 1:3 up to 1:25;

b) the mixture is allowed to compost for a first period of time;

c) Sulphur or a Sulphur rich component in an amount of between 1‰ to 10‰ by weight of the mixture is added to the mixture at any time during the first compost time but more preferably after ending this;

d) the mixture is allowed to compost for a second period of time, during which time the mixture is mixed occasionally in order to allow air into the mixture;

e) the temperature of the mixture is adjusted to be in the interval above 55°C up to 95°C for approximately 10 hours whereby the mixture is pasteurised;

f) the pasteurized mixture is cooled to below 50°C during a mixing process, which is maintained until preferably all free ammonia has been separated from the mixture;

g) the mixture is cooled to ambient temperature by ventilation, and thereafter optionally dried before being packaged, distributed on the soil or stored.

The texture of the mixture, and in particular the finished product, is of course very sensible to the amount of lignocellulosic material added. Tests, however, have shown that in the intervals mentioned above, the resulting product, i.e. the natural fertilizer, is stable in such a manner that it may be packaged and stored without having to provide special conditions for its storage, and at the same time it may be transported and distributed/spread in gardens, fields and the like without any problems, and without the

use of special implements. The texture will vary from a very thick sludge-like condition to a very dry material having a loose consistency.

The term "solid fraction" is within the definition used for this invention material or mixture where the moisture content is 70% or less.

The added Sulphur (e.g. S_8 or other Sulphur rich component) will, due to the interaction of the bacteria and oxygen, be biologically oxidized from Sulphur to acid protons (H^+) and sulphate ions (SO_4^{--}) according to the following reactions:

$$S_8 + 10\,O_2 + 12\,H_2O \rightarrow 24\,H^+ + 8\,SO_4^{--} \quad (1)$$

Every mol H^+ produced will utilise one mol NH_3 to NH_4^+ according to the following reactions:

$$H^+ + NH_3 \rightarrow NH_4^+ \quad (2)$$

The NH_4^+ fraction will be a component in the manure compost, or will be present as ammonium sulphate due to the following reaction:

$$2NH_4^+ + SO_4^{--} \rightarrow (NH_4)_2SO_4 \quad (3)$$

The Sulphur oxidation processes described in equation (1) is caused by the interaction of the bacteria *Thiobacillus thiooxidans*. These bacteria are already present in the manure, but may advantageously be added to the mixture as described in a further preferred embodiment of the invention. By adding a batch of *Thiobacillus thiooxidans* bacteria, the composting process will be accelerated, and at the same time it is assured that a sufficient amount of bacteria is present in the mixture in order to create a substantial complete composting process in an effective manner.

The ammonia is temporarily bound in the manure as ammonia sulphate or will bind to the lignocellulosic fraction of the manure, which has a large cationic ion exchanging capability. This mechanism will substantially reduce the malodours as well as the evaporation of ammonia from the mixture, and at the same time counter the leaching

of macro and micro nutrients. During the compostation, other organic connections will be converted such as for example mercaptans and other malodorous connections, which further reduce the annoying odour emission.

Concurrent with these reactions, a normal compostation takes place, which by oxidation converts easily convertible organic matter to CO_2 and water. Among these easily convertible organic matters are the sugar based materials, cellulose and hemilullose which to a certain degree have become free agents due to the ammonia influence during the early phases of the compostation. During this process, other micro nutrients are liberated from the manure. The lignin content will, as mentioned above, temporarily harness the liberated micro and macro nutrients in a manner which is easy to absorb for the plants.

The resulting product is a substantially odourless product which is rich on easily accessible organic micro and macro nutrients (among these Sulphur), which will improve the growth of the plants, and in particular the synthesis of proteins, vitamins and enzymes. The product will, due to its characteristic non-smell, not be associated with manure, and the physical presence of the material will, as already mentioned above, be comparable to soil.

The method may readily be used on farms, and the resulting product/mixture will be useable directly in the fields, in nurseries, gardens and anywhere else where it is desirable to improve the quality of the soil by complementing the soil with natural nutrients.

A further advantage is obtained with the fertilizer product according to the invention in the fact that the fertilizer will, in particular in comparison to the "pure" manure, release the nutrients at a slower rate whereby the plants will be able to use a greater percentage of the nutrients. When manure is spread on the fields, a large percentage is washed directly out into the aquatic environment where it causes new problems (oxygen depletion, excessive algae growth, etc.).

In a further advantageous embodiment of the invention it is foreseen that the Sulphur or Sulphur-rich component added in method step c) may, for example, be added by

means of percolating a Sulphur containing gas through the mixture or by adding a Sulphur rich liquid

Also, the family of bacteria with the genus *Thiobacillus*, for example *Thiobacillus thiooxidans or Thiobacillus ferrooxidans*, may be added or added as a supplement to the *Thiobacillus thiooxidans* in that these bacteria also will create the necessary oxidation whereby the odour generating substances are oxidised, and thereby become harmless as a odour component.

By reducing the liquid content in the manure as proposed in a further embodiment of the invention, the resulting mixture will have a more granular characteristic. Also, during the process less water has to be evaporated during the pasteurisation and ventilating steps of the method. In this connection, it should be mentioned that in method step d) of the method according to the invention, the mixture is remixed occasionally such that a thorough compostation of the entire mixture will be facilitated, and at the same time during the compostation oxygen will be present and be mixed in, such that a substantially complete and rapid oxidisation, and thereby compostation, may be achieved.

Due to the chemical reaction and the activity of the bacteria, the temperature in the mixture will rise to such a level in the interior of the mixture that it may be necessary to remix the mixture in order to release some of this heat which otherwise would kill certain micro organisms present in the mixture.

In order to further provide a mixture which is easy to handle and disperse in a garden, nursery or the like, a drying step may be provided as foreseen in a further embodiment where the energy for the drying of the mixture may be collected from the composting processes, and thereby reused in this drying step.

The inventive mixture which is the result of the method according to the invention may be further improved or given special characteristics by adding one or more additives as proposed in a still further embodiment of the invention, where additives such as crushed lava, clay minerals such as bentonite, perlite, vermiculite, smectite, kaolinite, illiteand other comparable minerals, gypsum, flyash, microsilica, silt and sand or

other minerals, macro nutrients (Nitrogen, Phosphorus, Potassium, Magnesium, Calcium), micro nutrients (Iron, Manganese, Zinc, Copper, Boron, Molybdenum, Chlorine, Nickel, Sodium, Selenium, Cobalt, Iodine, Vanadium or rare earth elements), meat or bone flour, sea shells optionally crushed, fish residues, ash and biomass containing residues from power and electricity, and biomass from plants algae, plankton, sea weed or sea grass, water hyacinths, elephant grass, willow, other energy crops are introduced. The additives may be introduced into the mixture at any appropriate step in the method.

By addition of the above-mentioned clay, silt, and sand components, more soil structure of the resulting mixture is obtained, resulting in reduced washout effect, due to enhanced cat ion exchange capacity of the mixture.

By addition of the other mentioned minerals, ash and biomass containing materials, the invented fertiliser is further enriched with micro and macro elements resulting in a more rich fertiliser. Further, introduction of more biomass components may enhance the composting process and adjust the mixture and thus the end product to a desired composition.

Finally one or more of the micro- and macronutrients mentioned above can be added, if needed, to adjust the mixture to obtain an especially desirable product.

In addition to additives as mentioned above, also enzymes may be introduced into the mixture, for example cellulases, hemicellulases, lacases, amylases, proteases, pectinases. By introduction of more enzymes, more biomass degradation occurs during the composting process, and thus the total composting time is being reduced.

The pH value of the mixture is a good indication of the ammonia content and thereby the smelliness of the mixture. During the process step a) to d) (se claim 1) pH will fall from a level of approximately 8 down to 6-7.

The invention also comprises a facility for the manufacture of a natural fertilizer, enriched soil or the like according to a method described above. The facility comprises:

- a first mixing chamber, where optionally dispensing means are provided for dispensing Sulphur or a Sulphur rich component to the interior of the mixing chamber, and that a mixing device is arranged for creating a mixture of the materials introduced into said mixing chamber;
- a composting chamber optionally comprising dispensing means;
- a first means for transporting the mixture from the mixing chamber to said first composting chamber;
- a pasteurizing chamber including mixing means, temperature control means and heating and/or cooling means;
- second means for transporting the mixture from the composting chamber to the pasteurizing chamber;
- a storage chamber comprising cooling and/or ventilation means, and a mixture outlet means;
- a third means for transporting the mixture from the pasteurizing chamber to the storage chamber.

In a further embodiment of the facility according to the invention, one process chamber is arranged to be both composting chamber, pasteurizing chamber and storage chamber, and that only conveyor means are provided between the mixing chamber and the process chamber.

The facility for the manufacture of a natural fertilizer according to the invention may be carried out in a number of different ways. Below, three different embodiments will be described which all are contemplated within the inventive idea of the present invention.

In a first embodiment, the manure is placed on the floor of a factory building where the manure is laid out in an elongated pile, for example 50 metres long, 2 metres wide, and 2 metres high. A composting machine comprising one or more large drums having spikes extending from said drum where the spikes have an approximate length of 20 centimetres is thereafter advanced through the pile of manure. The cylinder is rotated and during the rotation the spikes will grab the manure and tear off sections of the manure which during the transport through the compost machine will be aired.

During this process, straw - for example straw from any cereal products such as wheat, oat, barley or the like - may be added in predetermined amounts such that the mixture of straw and manure on the rear side of the composting machine will be a mixture comprising both manure, both also straw. Advantageously, the straw may be shredded prior to being introduced into the composting machine in order to distribute the straw content more evenly in the manure, whereby a substantially even distribution of straw and manure will be obtained in the mixture.

The first mixing chamber may, therefore, be compared to the building in which the original manure pile is placed, and the same building also acts as composting chamber in that the mixture on the rear side of the composting machine will begin to compost due to the presence of manure, straw and oxygen. In order to further increase the composting process and the chemical reactions as described above, Sulphur or Sulphur rich components may be added to the mixture during the manure's passage through the composting machine, i.e. at the same time as the straw (shredded straw) is added to the manure in order to create the mixture.

The composting chamber may, furthermore, comprise dispensing means for dispensing Sulphur and/or bacteria, enzymes or one of the other desired components mentioned above, and these dispensing means may be arranged in the composting machine such that during the first passage of the composting machine through the pile of manure, Sulphur or a Sulphur rich component is added to the mixture. By reversing the travelling direction of the composting machine such that it will, again, work its way through the pile of mixture, the mixture is aired and mixed. At this time, the dispensing means already present in the composing machine may be used in order to add extra bacteria such as for example *Thiobacillus thiooxidans* or other related bacteria cultures which will oxidize the constituents of the mixture and thus fixate Ammonia and reduce/remove odour (see equation 1 and 2 above)

The following step of pasteurizing the mixture may be carried out by creating a pasteurizing chamber, for example by covering the pile of mixture with an insulating cap, and increasing the temperature inside the mixture to the required 55°C. The heating and/or cooling means may be in the shape of ventilating lances inserted into the mixture through the insulating cap such that, depending on the temperature in the mixture, hot or cold air may be forced into the mixture in order to cool or heat the mixture to

the desired temperature range. At consistent temperatures above 55°C, a number of micro organisms will be killed, and at the same time a number of seeds, and in particular seeds which could give rise to weed growth, will loose their ability to sprout. The temperature should be kept under 95°C in that it is not desirable to kill off the micro bacteria which facilitates the composting and the conversion of manure and straw components to micro and macro nutrients, as well as the synthesis of proteins, vitamins and important enzymes. The building in which the original pile of manure was placed may also constitute the storage chamber in that the floor may have a double floor wall construction as well as gratings in the top floor such that air may be forced into the space between the two floor levels, and due to the gratings arranged in the floor, the air will be forced up through the mixture such that it will be ventilated, dried, cooled and ready to be stored. In this manner, all processes may take place in the same building which then will act as the process chamber.

In use, the finished mixture may be loaded onto trucks and distributed to farms in bulk, or the mixture may be packaged in individual sacks for sale, for example in garden markets for private use in gardens, either in its original form or after pelletising, where it often is desired to have a smaller quantity. Pelletising may also be advantageous for farm use in that the mixture according to the invention may be distributed in the fields by machinery already used on the farms.

As the composting process develops a significant amount of heat, it is desirable to provide an installation such that this energy may be collected and reused, for example for the pasteurizing and drying process. Also, due to the composition of the manure, a certain amount of gas will evaporate from the pile of manure, and also from the mixture during the initial composing stages. This gas may advantageously be collected and used for heating processes, for example for heating the air used to control the temperature in the pasteurizing step and/or heat the air used for ventilation of the mixture.

Depending on the desired consistency of the finished mixture, the manure may be separated prior to being treated in the facility according to the present invention. For this purpose, a manure separator, for example a cyclone or a rotating grading system may be installed, such that the liquid or a substantial part of the liquid may be drained

off and led to a collection tank before the substantially solid manure fraction is introduced into the mixing chamber.

Returning to the other contemplated ways of carrying out the method, a facility comprising a mixing chamber, for example in the shape of a tank, is provided. The manure, both the liquid and the solid fraction, is poured into the tank which is the mixing chamber, and straw either as a whole or previously shredded straw, is also unloaded into the tank. Mixing means, either in the shape of paddles arranged in the tank or other mechanical means, are thereafter activated in order to mix the substantially liquid manure with the straw.

During this process, the mixture becomes substantially firm such that it looses its liquid stage. A large amount of the liquid is absorbed in the straw material. This in turn facilitates the use of a composting machine or the like to create a further mixture in that the composting machine, for example having a similar configuration as the composting machine described above, will provide a substantially even distribution of manure and straw in the resulting mixture. Once the mixture in the tank has reached the substantially non-fluid stage where a substantial part of the liquid has been absorbed by the straw, it is possible to remove the tank or to unload the mixture from the tank such that the composting machine may be advanced through the pile of mixture in a similar manner as described above.

The mixture may be left in the tank in order for the tank to function as the composting chamber, or the mixture may be removed such that the tank may be used for a new batch of raw materials, i.e. manure and straw.

The straw which is added to the manure may be whole straw or shredded straw. During the composting process, the straw will decompose due to the action of the bacteria, and thereby the straw will become very brittle. This means that during the mixing processes, the straw will disintegrate and only be present in the mixture as very small parts.

Once the deposited mixture, whether it is in the tank or a separate composting chamber, for example as a pile inside a building as explained above, the composting takes

place. Alternatively, the composting chamber may be a second tank in which tank temperature control means and heating or cooling means are provided such that the pasteurisation may take place after completion of the composting. The advantage of placing the heating and/or cooling means in the composting chamber and in this manner create a combined composting and pasteurising chamber is the fact that during the composting process, the means for heating and/or cooling which may be in the shape of water piping may be used as a heat exchanger such that the excess heat produced during the compositing process may be extracted through the water piping and reused, for example in a parallel facility for heating the ventilation air or heating in the pasteurising process.

Eventually, the pasteurised mixture must be cooled, and optionally ventilated in order to vent off the last remains of ammonia. This may advantageously be carried out in a third tank in which tank there is a double bottom, where the top bottom at least in sections comprises grating such that it is possible to force air into the space between the two bottoms up through the gratings and in this manner ventilate air through the mixture. Usually, it will be air that is ventilated through the mixture, but any oxygen containing gas may be used in that the oxidisation of the chemical compounds contained in the mixture will neutralise many of these compounds, and thereby neutralise the odours.

As already discussed above, the main odour generating component in a mixture comprising manure in the amounts of the present invention will be the presence of ammonia. Research, however, has indicated that the odour deriving from manure comprises more than 200 different odour agents which all have distinct odours and which are not registered as pleasant odours by bystanders. As the ammonia content is reduced, as explained above, also the emission of odour due to this component is substantially eliminated. From the other 200 plus odour generating substances a number of these are neutralised due to the action of the micro bacteria processes as well as the generation of different chemical compounds which, as explained above, are converted from constituents of the manure or straw into micro as well as macro nutrient which are stable salts.

A third installation is contemplated as a mobile unit where, on for example a flatbed trailer, a mixing facility is placed. The mixing chamber comprises an inlet for introducing manure and lignocellulosic material into the mixing chamber as well as mixing means provided inside the mixing chamber. The necessary dispensing means for dispensing Sulphur are also arranged in the mixing chamber. This facility is particularly foreseen for small batch productions, and the facility may be transported to a farm such that, as will be evident from the description below, as the facility has treated the manure and straw, a pile of finished fertilizer will be available at the farm without the logistic and costly steps of transporting both manure and straw to the facility for the manufacture of natural fertilizer, but rather taking the facility to where the raw materials are present in the first place. In this fashion, it is only necessary to transport the facility and the necessary amount of Sulphur.

From the mixing chamber, a conveyor will convey the mixture to a composting chamber. The composting chamber may be in the shape of a standard Euro container such that the mixture is dumped inside the container, for example through an opening at the top of the container. The container may advantageously be placed next to the trailer. Before the new mixture is placed in the composting container, the container may have been emptied from already composted mixture, which mixture is introduced into a pasteurising chamber present on the flatbed trailer. The pasteurising chamber may further include means for controlling the temperature which is necessary in order to carry out the pasteurising process, but will also comprise means arranged in the bottom such that an oxygen containing gas, which may be air, will be forced through the mixture placed in the pasteurising chamber in order to vent off remains of ammonia, water and to cool down the material at the end of the pasteurising process.

Eventually, the mixture which has been pasteurised, may be conveyed to a storage chamber which may be in the shape of a second Euro container from which the farmer, according to need, may collect the amount of fertilizer necessary. In this manner, the installation requiring machinery and control means may be built onto a flatbed trailer, whereas the passive storage means such as the composting chamber and the storage container may be rather cheap Euro containers placed in appropriate positions/locations on the farm.

In a further embodiment of the invention provisions are made in order to bind a larger part of the ammonium in the mixture. This may be performed in a number of ways, but of particular interest for the present invention are the following ways: prior to introducing the lignocellulosic material, for example straw to the mixture, the material may be soaked in a liquid, for example sulphur or sulphuric acid containing water, or liquid manure to which sulphur is added. This will lower the pH of the mixture and thereby bind more ammonium (as ammonia) in the mixture.

Sulphur is, in its commercially available form, a powder which is easy to handle and stable under normal working conditions, i.e. normal temperature, humidity etc. It is therefore relatively uncomplicated to mix the desired sulphur content into the lignocellulosic material prior to introducing the material into the mixture with manure. This being particularly true when the sulphur is added dissolved in a liquid, whether it be water or the liquid manure fraction.

Alternatively, the lignocellulosic material may be wetted by a liquid containing a base, whereby the pH is elevated, but the lignin content in the lignocellulosic material (straw) is freed. This causes the composting process to be accelerated, due to the elevated biological activity, caused by the accessible amount of lignin.

The above aspects may be performed whether separated or unseparated manure is used as raw material in the mixture, as disclosed within the present invention.

Description of the Drawing

The invention will now be explained with reference to the accompanying drawing, wherein

Fig. 1 illustrates a flow sheet demonstrating one example of the method, and

Figs. 2, 3 and 4 illustrate three different embodiments of carrying out the method in different facilities.

Detailed Description of the Invention

In fig. 1, a flow sheet of how the method may be carried out in an embodiment of the invention is illustrated, where prior to creating the mixture comprising manure and straw the manure is separated into a liquid and a solid fraction. The liquid fraction is disposed of or used for other purposes, and the solid fraction is introduced into the composting process. In this embodiment, the separation of the manure is carried out to a degree where the solid fraction comprises 70% water. It should be noted that within the present invention it is contemplated to use solid fractions having less than 70 % water (liquid) for example 60 % or less, in that the moisture content may readily be adjusted at different stages during the process. This level of water, e.g. 70 % in the solid fraction may be obtained by use of a commercially available manure separator, for example available by the McLanahan corporation of Pennsylvania, United States of America.

Straw and air is then added to the manure such that the mixture is created which by further addition of Sulphur and more air will be the raw material of the finished fertilizer material. After the addition of Sulphur, the bacteria *Thiobacillus thiooxidans* which already is present in the manure, will oxidise the components as explained above and thereby neutralise the odour generating substances, and at the same time convert some of the compounds of the mixture into micro and macro nutrients which are desirable in a fertilizer. During the compostation which will last approximately five days, the amount of odour generating substances diminishes dramatically, and this may further be accelerated by the addition of additional bacteria.

The temperature inside the mixture during the composting phase will reach approximately 75-80°C, and during the composting process CO_2, water and heat will be generated, and water and CO_2 will evaporate from the mixture. During the composting phase, i.e. the five days, the mixture may advantageously be remixed a couple of times in order to improve the compostation of the materials, and such that materials on the outside may be mixed into the inside where a higher process temperature is present.

The mixture may for example be 10 tons of dryer fractions of manure mixed with 1 ton of straw, which will provide for a finished product having a substantially moist and loose characteristic which is easy to use and distribute in the places where it is

necessary. The reason for remixing the mixture during the compostation process is the fact that the Sulphur when exposed to oxygen converts into sulphates and acid, whereby the pH is lowered, and thereby the smell will also diminish.

During the composting process other additives may be introduced into the mixture. The additives introduced at this point may provide special characteristics or additional nutrients. For example, at this point crushed lava may be added. It is well-known that soils containing lava are very fertile, and this may be due to the content of macro nutrients present in the lava. Therefore, by adding crushed lava to the mixture, an additional macro nutrient is introduced. Other materials which may be added for the same or different reasons may be different clay minerals such as for example bentonite, perlite, vermiculite, smectite, kaolinite, illiteand other comparable minerals. Perlite, vermiculite and smectite are very light materials which will provide soil improving characteristics, particularly when the mixture containing these materials is introduced into so-called heavy soils, i.e. soils having a high clay content, which otherwise may not have the characteristics of a fertile soil. Gypsum, flyash, microsilica and other comparable minerals may be introduced in order to provide important salts, in particular metal salts, whereas meat or bone flour, sea shells optionally crushed sea shells, fish residues, algae, plankton, sea weed or sea grass, water hyacinths, elephant grass, willow and other energy crops may be introduced in order to introduce extra nutrients and important vitamins and proteins to the fertilizer. In particular, materials derivable from the sea such as for example sea shells, fish residues, algae, plankton, sea weed or sea grass are high in important proteins that may provide for an extremely fertile soil.

During the pasteurisation stage of the method, the temperature is increased to above 55°C. Typically, the temperature will be maintained at 58°C for approximately ten hours. The ten hours are calculated from the time when the average temperature in the mixture has reached 55 or 58°C depending on the desired pasteurisation temperature. The by-product of this pasteurisation process will be heat and a certain amount of water evaporating from the mixture. After the pasteurisation step, a cooling step may be introduced which at the same time will vent off any residue ammonia present in the mixture which will neutralise any remaining odour generating substances. The heat used for cooling as well as heat generated during the pasteurisation process may be regenerated and recycled for use in a drying step where the finished mixture may be

dried to a desired moisture content. The moisture content may be important depending on the storage facility of the finished product as well as the desired finished texture of the mixture in use. After the drying step, the mixture is finished and ready to be used as a fertilizer, enriched soil product or the like.

Turning to fig. 2, a first facility according to the invention is illustrated.

In fig. 2a, the manure, in particular the solid fraction of the manure 10, is placed on the floor 11 of the facility. The facility may be a building or anywhere where it is possible to store a rather large amount of manure/mixture for a long period of time shielded from the environment. A composting machine 12 is advanced through the pile of manure 10 in the direction of the arrow 13. The composting machine comprises a shield 14, a mixer 15 as well as wheels 16, where the wheels are adapted to propel the mixing device 12 in any direction.

The mixer is, typically, a cylinder arranged for rotation around an axis perpendicular to the travelling direction 13, and where the cylinder is provided with spikes 17 such that the spikes, as the machine advances into the pile of manure 10, will tear the manure apart and thereby introduce air into the manure.

With the present invention it is an object to add straw or other lignocellulosic material to the manure. This material, for example in the shape of straw, may be placed on top of the pile of manure 10, or may be introduced during the mixing process, for example by unloading suitable amounts of straw into the shield 14 such that the manure and the straw will be thoroughly mixed together as the composting machine 12 advances through the pile of manure 10. The resulting mixture 20 will have a volume larger than the initial manure pile 10 due to the add mixture of straw and air.

The straw and the air will, together with the micro organisms and in particular the bacteria, create the composting process. By additionally adding Sulphur to the mixture 20, for example during the advancement of the composting machine 12 through the manure pile 10 such that a thorough in-mixing of the Sulphur or a Sulphur containing material is achieved, and thereby the composing process in the mixture 20 is further improved. During the composting time, the composting machine 12 may advanta-

geously be moved through the mixture 20 in order to ventilate the mixture and remix the mixture such that a thorough and even composting may be achieved in the pile.

The composting machine 12 may also be provided with a shield on the opposite side of the shield 14 illustrated in fig. 2a and 2b, whereby the second shield (not illustrated) will help to form the pile of mixture 20 such that for further ventilation of the compost as illustrated by the arrow 21 in fig. 2b, the composting machine may treat the entire pile of mixture 20 unhindered.

During the remix as indicated in fig. 2b, the straw or lignocellulosic material will decompose due to the decomposition of the sugar substances' reaction with the bacteria present in the manure in a sort of fermentation process such that as the mixture 20 is remixed, for example by passing the composting machine 12 through the mixture 20 in the direction indicated by the arrow 21, a finally divided mixture will be the result.

After having composted for approximately five days, where the composting temperature in the centre of the pile 20 will reach 75-80°C, the mixture 20 is transferred to the pasteurisation chamber 30, see fig. 2c. The means for transporting the mixture 20 to the interior of the pasteurisation chamber may be any suitable means, but for example a front end loader, travelling conveyor belt or the like may be used. In the illustrated embodiment, the pasteurisation chamber comprises a closed unit having a double floor construction 31,32. Between the two floors 31,32, air distribution channels 33 are arranged, which are in communication with grating 34 provided in the upper floor 31. Therefore, by introducing hot air/gas into the air distribution channels 33, this air will be distributed to the gratings 34 and thereby percolate through the mixture 20 placed on the upper floor 31 whereby the temperature inside the pasteurisation chamber 30 may be controlled to the desired temperature range of approximately 55-58°C for ten hours.

After pasteurisation, the temperature of the air introduced into the channels 33 may be lowered in order to cool down the mixture and at the same time dry the mixture to the desired moisture content. When the material from the outset comprises only the solid fractions of the manure as well as straw, for example in a mixture of 10 tons of ma-

nure to 1 ton of straw, the resulting moisture without drying at this step is normally within the desired range such that the drying step may be avoided.

The mixture is removed from the pasteurisation chamber 30 and placed in storage. In this embodiment, storage may be carried out by placing the mixture in a storage chamber 40 as illustrated in fig. 2d. In the illustrated embodiment, see fig. 2d, the storage chamber 40 is also provided with means for packaging of the mixture into bags. For this purpose, a conveyor 41 is provided inside the storage chamber 40 which is in communication with a further conveyor 42. The conveyor 42 offloads the mixture into a hopper 43 such that the mixture is introduced into a combined packaging and weighing unit 44. From this unit, the mixture is filled into bags 45 and transported for further storage by appropriate means generally designated 46.

In fig. 3, an embodiment of the invention is illustrated where the facility is especially designed to handle manure where the manure comprises both the liquid and the solid fractions. For this purpose, a tank 50 is provided in which tank both the manure as well as the lignocellulosic material are placed. The mixture 20 is created by either activating mixing means inside the tank 50 or providing mixing means which may be inserted into the mixture 20 such that the manure and the lignocellulosic material may be effectively mixed. During the mixing, Sulphur or Sulphur rich components are added and mixed into the materials such that an optimal distribution of Sulphur in the mixture is obtained. Furthermore, as it is the case with all the detailed embodiment of the invention, batches of bacteria, in particular *Thiobacillus thiooxidans* bacteria, may be added during the composting stage or the mixing stage. After the mixture 20 has composted for the desired amount of time, for example five days, the mixture 20 is transferred to a pasteurising tank 55. The transfer of mixture 20 from the composting tank to the pasteurising tank 56 may be carried out by conveying means in that the mixture 20 after composting will have a very low viscosity with a large content of solids such that it is suitable to be conveyed by traditional conveying means. Alternatively, front loaders or excavators may transfer the mixture 20 from the composting tank 50 to the pasteurising tank 55.

The pasteurising tank 55 is equipped with a heating installation 51. In this embodiment, the heating installation comprises a water heating mechanism where water is led

into the pasteurising tank 55 by means of hoses 52 which are connected to a pipe system 53 installed inside the tank 55. Additionally, heating lances 54 may also be inserted through the wall of the tank 55 such that heat exchange is possible between the mixture 20 placed inside the tank 55 and the heating lances 54.

The heating installation 51 may also be utilised as a heat exchanger in that if the mixture 20 is placed in the tank 55 before the compostation is finished, the mixture will still generate surplus heat from the compostation processes. By circulating cool water in the pipes 52,53 and possibly inserting the lances 54 into the mixture, it is possible for the mixture to transfer the surplus energy to the liquid circulated in the pipes 52,53,54 and by appropriate means arranged in the heating unit 56 to transfer the heat in a known manner to a secondary pipe system where the excess heat may be used for example for heating the air which is used for drying the mixture in a further process step.

The main purpose of the tank 55 is to pasteurise the mixture 20 and this may be done by introducing hot liquid in the pipes 52,53,54 in combination with temperature control means (not illustrated) such that a steady temperature in the range of 55-58°C may be obtained throughout the mixture 20 placed inside the tank 55 in order to achieve the desired pasteurisation process. Typically, this temperature will be maintained for ten hours or more, after which period of time the mixture will be transferred to the cooling and drying installation 60. This installation 60 is approximately equivalent to the installation described with reference to fig. 2c, but may further be equipped with a unit 61 for conditioning of the air used for ventilation. The unit 61 may add fresh air and reuse air from the ventilation tank in order to provide the optimum ventilation air into the air inlets 33 such that the optimal ventilation process may be provided.

In fig. 4, a mobile unit 100 is illustrated which unit may be transported to any desired location, for example onto a manure producing farm. Traditionally, manure 10 is stored in tanks 101 on the farm and straw is collected from the fields and stored in huge bales of straw 102. It will, therefore, be of interest to create a mobile unit 100 which may be placed adjacent the raw materials, i.e. the manure 10 and the bales of straw 102. The mobile unit 100 may for example be arranged on a flatbed trailer 103. On a trailer 103, a mixing chamber is arranged having inlet means 105 as well as ap-

propriate mixing means 106 arranged inside the mixing chamber 104. Furthermore, the mobile unit comprises a pasteurisation and drying chamber 107 as well as a power pack installation 108. In use, the manure 10 will be introduced into the hopper 105, for example by appropriate conveyor means, and bales of straw or parts of bales will likewise be introduced into the mixing chamber 104. The mixing means 106 are activated in order to create a substantially uniform mass, and concurrently Sulphur may be added, for example through the inlet hopper in the predetermined amount. Also at this time, an extra batch of bacteria may be introduced into the mixture in order to assure an advanced composting process of the mixture.

After thorough mixing, the mixture is transferred to a first composting container 109. The composting container 109 may be a standard Euro container placed alongside the manure tank 101. The conveying means may for example be a conveyor structure either built into the mobile unit 100 or provided separately at the farm. Prior to transferring the mix from the mixing chamber to the composting container 109, the composting container may have been emptied of the previous batch of mixture, which at this time is composted. This mixture has been introduced into the pasteurising/drying chamber 107 on the trailer where these processes will be activated as described below. Therefore, the composting container 109 may now be empty and ready to receive the fresh mix from the mixing chamber 104. The batch of composted mixture introduced into the pasteurising/drying chamber 107 will by means of the heating element 110 be brought to an appropriate temperature, for example as described above in the interval 55-58°C.

After having been pasteurised, for example during a ten hour period, a ventilator 111 is activated such that air is forced into a space between the bottom 112 of the pasteurising chamber and the trailer bed 103. By providing a large number of apertures in the bottom 112, the air will be forced up through the mixture placed inside the drying chamber 107 whereby the mixture placed in the chamber 107 may obtain the desired moisture content. Moisture may be measured by any known method, and may be automatically regulated and controlled such that both the heating by heating means 110 and the ventilation by the means 111 may be stopped at an appropriate time. After this time, the batch in the pasteurising/drying chamber 107 may be transferred to a storage container 115.

Working with the appropriate process times as mentioned throughout this specification, the mobile unit 100 should visit the farmer every 5-7 days, i.e. corresponding to the composting period, in order to process more manure and straw. The mobile unit must remain for at least the period of time it takes to carry out the processes described above, which may approximately last twenty hours.

In this manner, the only signs on the farm that a fertilizer producing process is underway will be the presence of two containers 109,115.

CLAIMS

1. Method for the manufacture of a natural fertilizer, enriched soil or the like, where the method comprises the following steps:

a) a mixture is created by mixing manure with one or more types of lignocellulosic material such that the ratio of lignocellulosic material to the solid fraction of the mixture is in the range from 1:3 up to 1:25;

b) the mixture is allowed to compost for a first period of time;

c) Sulphur or a Sulphur rich component in an amount of between 1‰ to 10‰ by weight of the mixture is added to the mixture at any time

d) the mixture is allowed to compost for a second period of time, during which time the mixture is mixed occasionally in order to allow air into the mixture;

e) the temperature of the mixture is adjusted to be in the interval above 55°C up to 95°C for approximately 10 hours whereby the mixture is pasteurised;

f) the pasteurized mixture is cooled to below 50°C during a mixing

g) the mixture is cooled to ambient temperature, and thereafter optionally dried before being packaged, distributed on the soil or stored.

2. Method according to claim 1 wherein a batch of *Thiobacillus thiooxidans* bacteria is added to the mixture and/or other related bacteria such as *Thiobacillus ferroooxidans Proteobacteria* as monoculture or in combination with other bacteria or fungi, preferably before step a) or between step a) and step b) or more preferably between step b) and step c).

3. Method according to claim 1 wherein either between step f) and g) or after step g) the mixture is ventilated by forcing an oxygen containing gas, such as for example air through the mixture and optionally that the mixture is oxidised or at least partly oxidised by Ozone or Hydrogenperoxide added at any step b), c) or d).

4. Method according to claim 1 wherein either of the following parameters and ranges may be applied separately or in combination:

- in method step a) the liquid content in the manure is reduced to below 80% more preferably below 70% and/or the preferred range of lignocellulosic material to solid

fraction of manure is from 1:5 to 1:15, an even more preferred range is from 1:8 to 1:12, and most preferred ratio is approximately 1:10;

- the first period of time is between 3 and 9 days, more preferred 4 to 7 days, and most preferred 5 days, and optionally forced ventilation of the mixture is arranged between 2 and 5 times;
- in method step c) Sulphur is added in an amount of between 0,5‰ to 70‰ more preferred between 1‰ to 10‰, most preferred 2 to 5‰.
- the second period of time is between 1 and 4 days, more preferred between 2 and 3 days.

5. Method according to claim 1 wherein the manure is obtained either separately or in combination from cattle, pigs, sheep, goats, horses, poultry, ducks, gees, or other husbandry, and that the manure optionally is separated in a solid fraction and a liquid fraction before being introduced in method step a), and where the lignocellulosic material is selected from one or more of the following: straw, wood chips, garden waste, hulls, husks, almond shells, dead litter (from e.g. horses or cattle breeding) used as it is in its original form or grinded cut or milled prior to the mixing, or where the manure is substituted or partly substituted with residue from a biogas plant, ethanol plant, waste paper, household waste, municipal solid or industrial waste.

6. Method according to claim 1 wherein one or more additives is/are added to the mixture between steps a) and b) and/or c) and d) and/or between e) and f) where the additives are selected from the following: crushed lava, clay minerals such as bentonite, perlite, vermiculite, smectite, kaolinite, illiteand other comparable minerals, gypsum, flyash, microsilica or other minerals, meat or bone flour, sea shells optionally crushed, fish residues, ash containing residues from power and electricity plants algae, plankton, sea weed or sea grass, water hyacinths, elephant grass, willow, other energy crops, where the macro nutrients are selected among : Nitrogen, Phosphorus, Potassium, Magnesium, Calcium where one or more of the macro nutrients are added to the mixture at any step a), b), c), d), e), f) or g), and where micro nutrients are selected among : Iron, Manganese, Zinc, Copper, Boron, Molybdenum, Chlorine, Nickel, Sodium, Selenium, Cobalt, Iodine, Vanadium or rare earth elements where one or more of the micro nutrients are added to the mixture at any step a), b), c), d), e), f) or g) and where one or more enzymes is/are selected from the following: cellulases, hemicellulases,

laccases, amylases, proteases, pectinases, where the enzymes are added to the mixture between steps a) and b) and/or c) and d), and optionally that the pH is adjusted by addition of acid e.g. Sulphuric acid, Phosphoric acid, Acetic acid to the mixture at any step a), b), c), or d).

7. Method according to claim 1 wherein steps e), f) or g) or at least one of them is/are omitted.

8. Facility for the manufacture of a natural fertilizer, enriched soil or the like according to any of the preceding claims, where said facility comprises:

- a first mixing chamber, where optionally dispensing means are provided for dispensing Sulphur or a Sulphur rich component to the interior of the mixing chamber, and that a mixing device is arranged for creating a mixture of the materials introduced into said mixing chamber;
- a composting chamber optionally comprising dispensing means;
- a first means for transporting the mixture from the mixing chamber to said first composting chamber;
- a pasteurizing chamber including mixing means, temperature control means and heating and/or cooling means;
- second means for transporting the mixture from the composting chamber to the pasteurizing chamber;
- a storage chamber comprising cooling and/or ventilation means, and a mixture outlet means;
- a third means for transporting the mixture from the pasteurizing chamber to the storage chamber.

9. Facility according to claim 8 wherein one process chamber is arranged to be both composting chamber, pasteurizing chamber and storage chamber, and that only conveyor means are provided between the mixing chamber and the process chamber.

10. Facility according to claim 8 or 9 wherein means are provided for regenerating the energy in the shape of heat from the composting processes and the pasteurizing process, and reuse this energy in the process, and that optionally biogas collection means are provided in the composting chamber.

11. Facility according to claim 8 wherein a manure separator is arranged adjacent the mixing chamber, where said manure separator comprises means for conveying the solid manure fraction into the mixing chamber and means for directing the liquid manure fraction to a collection tank.

12. Facility according to claim 9 wherein the process chamber comprises a plurality of cells, where each cell is between 10 m and 50 m long, between 2m and 5m wide and between 2 m and 7 m high, and that in one alternative a double floor is provided, where means for introducing ventilation air in the space between the double flooring is provided, and the uppermost floor comprises areas having gratings or other ventilation openings, and that the lower floor comprises drain and liquid collection facilities, or in another alternative ventilation pipes are arranged on the floor of said process chamber; that a ventilation installation is provided where said ventilation installation comprises a ventilator, an air mixing chamber where said air mixing chamber comprises an inlet for fresh air and an inlet for air from the cells and an air outlet.

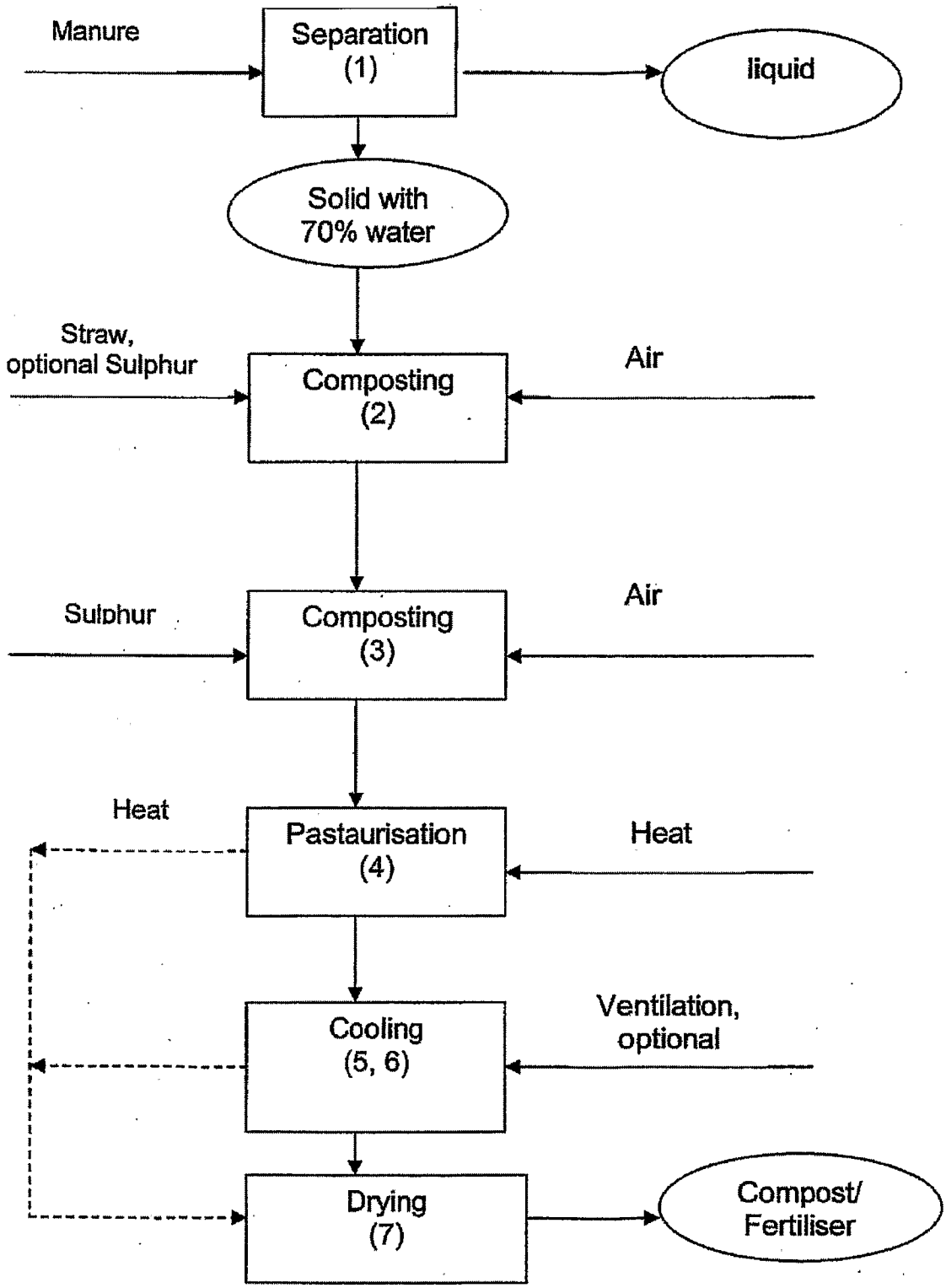

Manure
Separation
(1)
liquid
Solid with
70% water
Straw,
optional Sulphur
Composting
(2)
Air
Sulphur
Composting
(3)
Air
Heat
Pastaurisation
(4)
Heat
Cooling
(5, 6)
Ventilation,
optional
Drying
(7)
Compost/
Fertiliser

FIG. 1

FIG. 2a

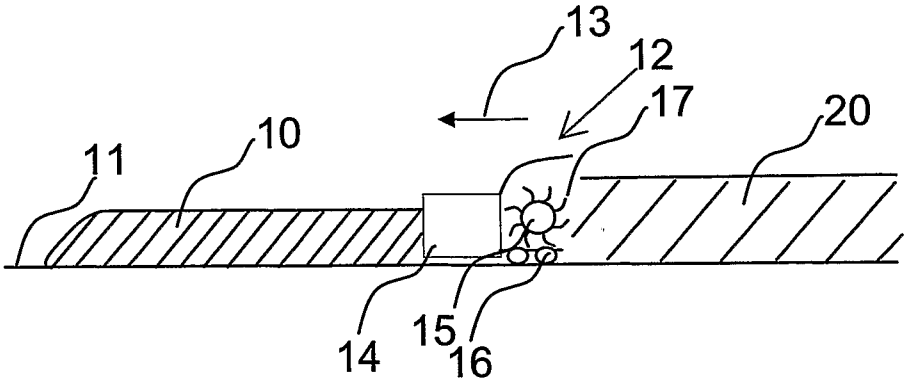


FIG. 2b

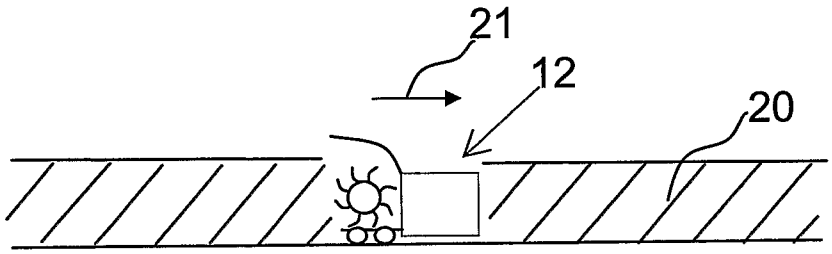


FIG. 2c

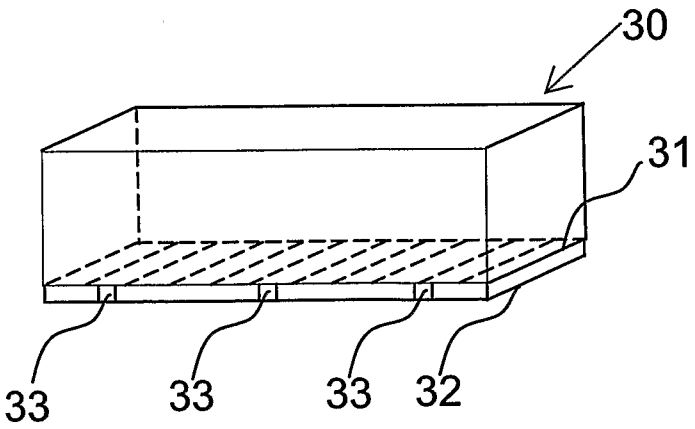
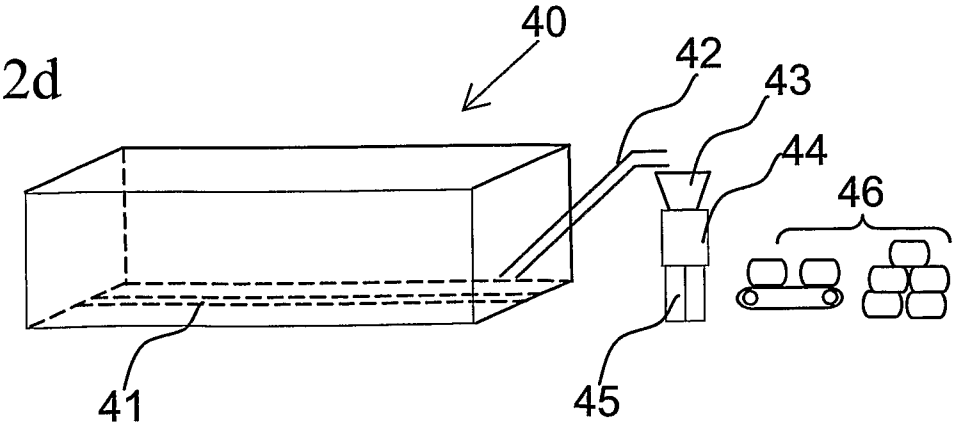


FIG. 2d



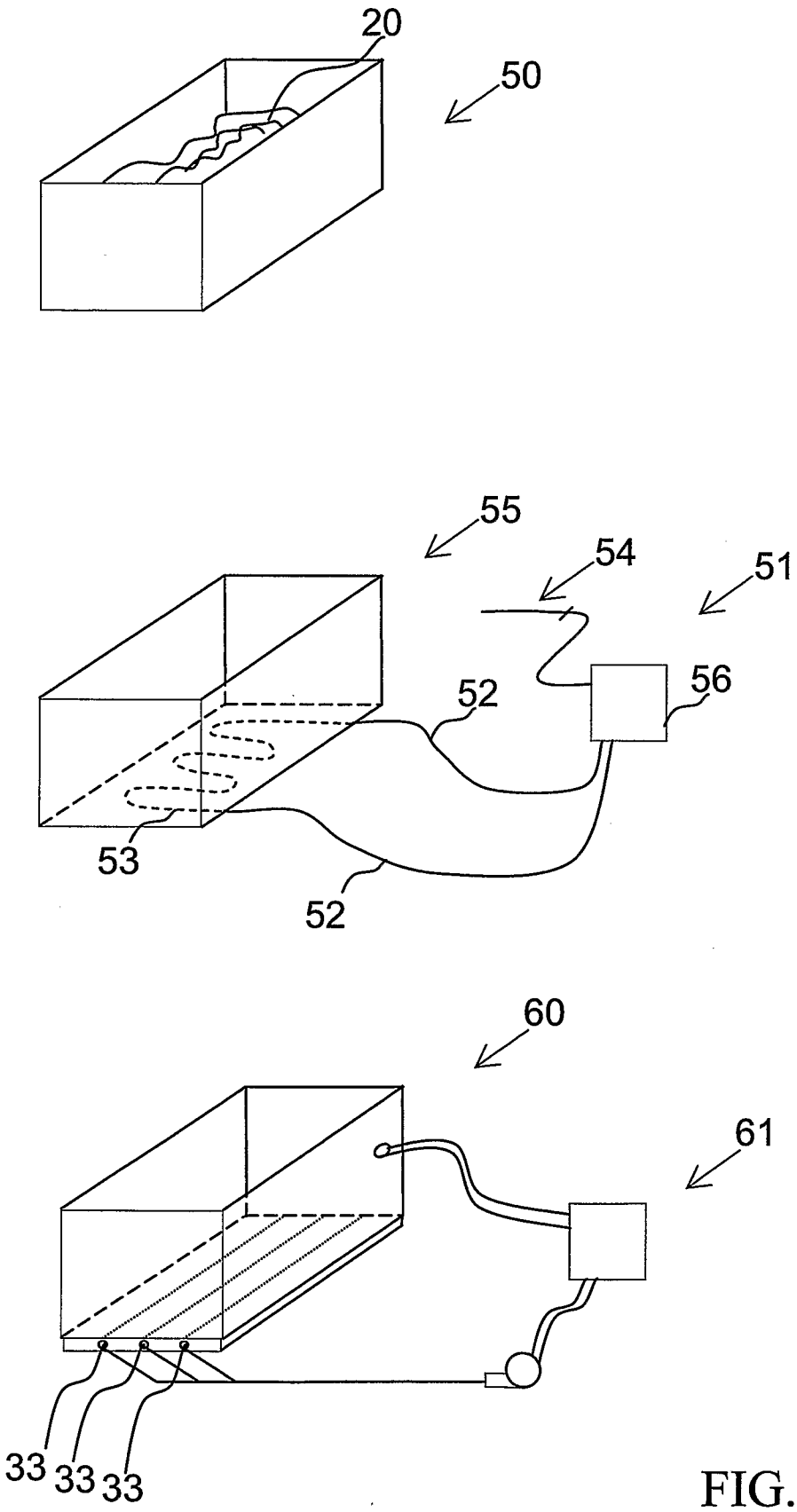


FIG. 3

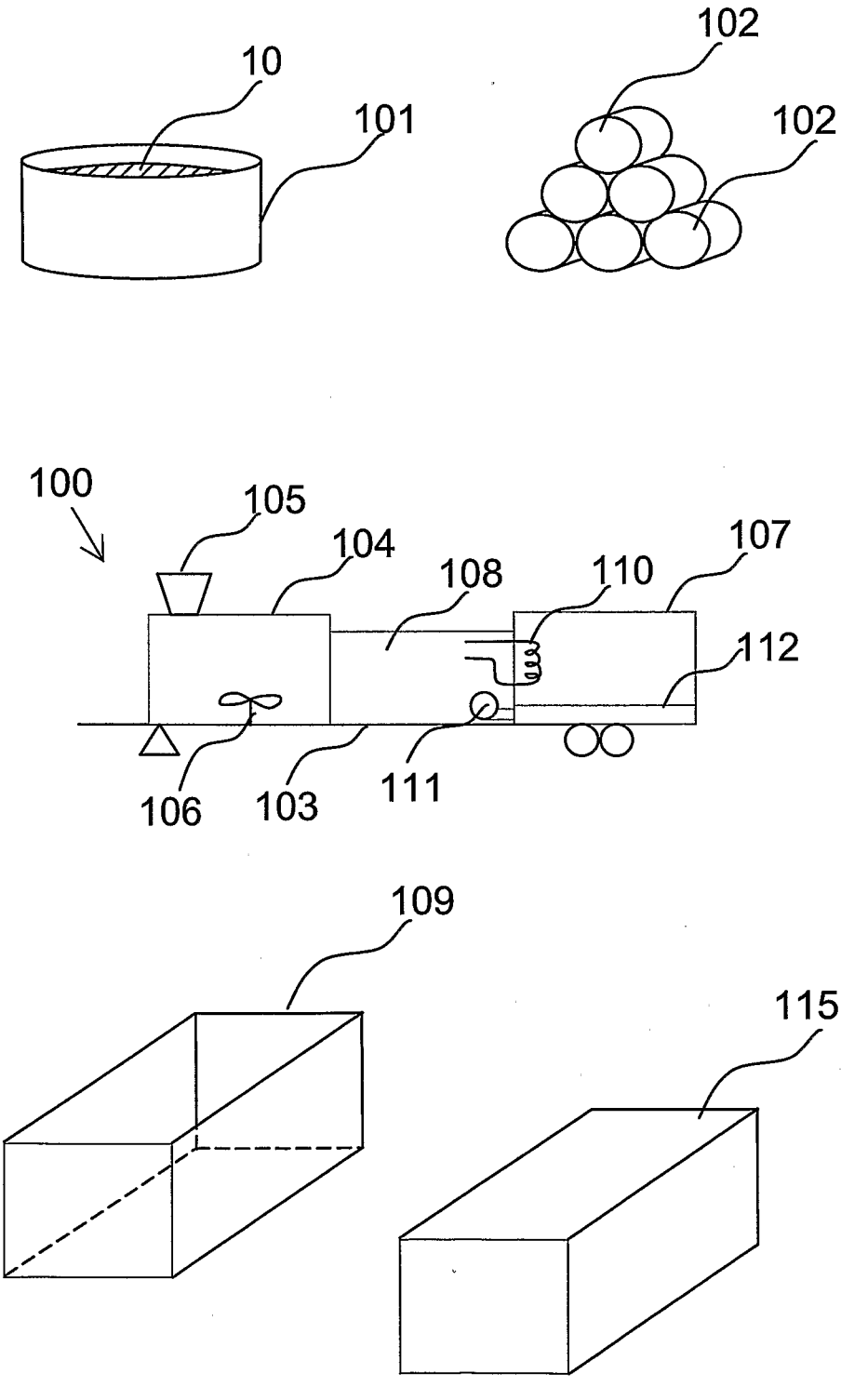


FIG. 4