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(54) Title: PHOTOBIOREACTOR AND METHOD FOR THE PRODUCTION OF PHOTOTROPIC ORGANISMS

(57) Abstract: The present invention relates to a photobioreactor for the production of phototropic organisms, especially (micro)algae, where the reactor comprises: - at least a reactor component into which a mixture of a liquid and phototropic organisms has been or is to be introduced, where said reactor component comprises a reactor vessel and one or more tubes connected to the reactor vessel, the reactor vessel is essentially protected from daylight, and the tubes are at least partly transparent, so that daylight can penetrate the reactor component to enable the organisms to carry out their photosynthesis; - one or more floats to ensure buoyancy for at least the tubes of the reactor component when the bioreactor is placed in an expanse of water, especially a lake or the sea. The invention also relates to a method for the production of phototropic organisms, especially (micro)algae, which method comprises: - the provision of a photobioreactor; - the introduction of a mixture of a liquid and phototropic organisms into the photobioreactor; - the placement and floating of at least the transparent tubes of the bioreactor in an expanse of water, especially a lake or the sea; - growing the microorganisms under the influence of daylight entering the transparent tubes.

PHOTOBIOREACTOR AND METHOD FOR THE PRODUCTION OF PHOTOTROPIC ORGANISMS

The present invention relates to a photobioreactor for the production of phototropic organisms, especially (micro)algae. The invention also relates to a method for the production of phototropic organisms.

Photobioreactors are reactors in which phototropic microorganisms, such as (micro)algae and bacteria, can be cultured. The microorganisms are mixed with a liquid, for example water, and introduced into the reactor. The growth of the organisms in the reactor is stimulated by the addition of carbon dioxide (CO_2), as a result of which photosynthesis takes place under the influence of the light entering the bioreactor. In this process, carbon dioxide is converted in energy-rich compositions and various useful substances (biomass).

The possibility of producing biomass by photosynthetic techniques has been known for a number or years now. Scientists have also recognized the great importance of the possibility of using simple microorganisms such as algae to convert sunlight and carbon dioxide into complex organic substances, with the release of oxygen.

Beside carbon dioxide, other nutrients, such as phosphorus (P), nitrogen (N) and certain metals, are also needed for stimulating algal growth. When growing algae in a bioreactor, it is important to add a suitable amount of nutrients, such as carbon dioxide, phosphorus and nitrogen, to the mixture of algae and water. The nutrients and/or carbon dioxide are often already present in a large quantity, because they are released for example by industrial plants. The required amount of light is also normally freely available, since sunlight can be utilized. However, in certain embodiments, artificial lighting can be used either instead or in addition to sunlight. Nutrients can also be added to the mixture in the bioreactor separately.

Two basic types of photobioreactor are currently known: the open and the closed type. In closed photobioreactors, the exchange of gases, water and contaminants between the culture and the surroundings is restricted, while in open photobioreactors (also called "open pond" systems) the culture is directly exposed to daylight. Bioreactors of the open type are relatively simple and cheap to construct, but they suffer from a number of drawbacks. One of the main shortcomings of this type of bioreactor is that the culture is affected by environmental factors, such as for example temperature fluctuations, contamination of and by the air, and so on. It has also been found difficult to set the physical or chemical parameters for controlling the process of microorganism formation, partly because of the relatively great influence of the environmental factors. Photobioreactors of the closed type have e.g. the following advantages over the open type: better control of the microbial culture because of less external influence, a greater surface/feed ratio, better regulation of the gas transfer, better control of the light intensity, reduction of the evaporation of the medium, uniform temperature, and a better protection from external influences or contamination.

It appears from what has been said above that closed photobioreactors are preferable for the production of large amounts of biomass. A particularly effective design of such bioreactors uses a number of elongated tubes in which the organisms (usually algal cells), nutrients, liquid (usually water) and carbon dioxide are circulated, these tubes being transparent in order to maximize the amount of light reaching the algae. In addition to the transparent tubes, there is also a non-transparent feed vessel to ensure that the algae also experience what is called a dark phase, in order to stimulate their more complex protein forming function. A stream of nutrients and carbon dioxide is introduced during the dark phase of this process. The biomass produced in the bioreactor is periodically removed from it and subjected to further processing.

The biomass can be processed in many different ways, depending on its end use. Conversion into biodiesel is an important application of biomass. For this purpose, the biomass is first dried, for example by first centrifuging and then drying it further. The dry biomass is then pressed, giving algal oil, amongst other things. This algal oil can be used to make biodiesel.

The existing bioreactors are placed on land, which means - especially if they are set up in a warm climate - that the temperature of the medium in the reactor can reach very high values, owing to the sunlight passing through the transparent tubes, or owing to the heat of the air around the reactor. At an air temperature of about 25°C or more and/or when a great deal of heat radiation is delivered by the sunlight, the temperature inside the reactor can reach excessively high values. If for example microalgae are used as the microorganisms, their growth rate drops already when the temperature in the tubes exceeds about 27°C.

Bioreactors are known that are fitted with a cooling device in order to keep the temperature of the medium in the bioreactor sufficiently low even if the air temperature of the surroundings is relatively high or a great deal of radiant heat reaches the reactor. However, such cooling devices make the reactor more complicated and more susceptible to disturbances. In addition, cooling the reactor means a loss of energy, so the net output of the bioreactor is reduced.

One of the aims of the present invention is to provide a photobioreactor and a method for the production of phototropic organisms, especially (micro)algae, which are free of the above drawbacks present in the prior art.

According to a first aspect of the invention, at least one of the above aims is reached by a photobioreactor for the production of phototropic organisms, especially (micro)algae, which reactor comprises:

- at least a reactor component into which a mixture of a liquid and phototropic organisms has been or is to be introduced, and which reactor component comprises a reactor vessel and one or more tubes connected to the latter, where the reactor vessel is essentially protected from daylight and the tubes are at least partially transparent, so that daylight can penetrate the reactor component in order to enable the organisms to bring about their photosynthesis;

- one or more floats or buoyancy aids to enable at least the tubes of the reactor component and preferably also the reactor vessel to float when the bioreactor is placed in an expanse of water, especially a lake or the sea.

By placing the bioreactor or at least the transparent tubes in an expanse of water, such as for example (but not exclusively) a lake, canal, pond or the sea, the water can be used to cool the bioreactor or at least its transparent tubes, for example to a suitable temperature that promotes the growth of the organisms. The water that is normally already present can be utilized here, so that an extra apparatus, such as a cooling device, can be dispensed with or at least it can be made less substantial. In an embodiment where the tubes are fully or partly immersed in the water, the bioreactor according to the invention has the following additional advantages. The transparent tubes are automatically kept clean on their outside surface by the expanse of water, which can reduce the cleaning cost. If the tubes are placed below the surface of the water, the layer of water above these tubes acts as a UV filter. Filtering the light has a positive effect on the growth of the microorganisms in the reactor component. If in addition the bioreactor is placed in an expanse of water that is subject to a certain swell, this movement ensures that the contents of the reactor are shaken. This can improve the mixing of the constituent parts of the mixture and lead to an improved growth of the microorganisms as a result.

The floats can be formed in the bioreactor, especially the reactor component itself, for example in the form of float chambers in the tubes, but separate floats are also possible. In this last case, the floats can be attached to the tubes and can consist of inflatable or other devices filled with a gas, or devices with a solid filling, such as for example PE or XPS.

According to a preferred embodiment of the invention, the buoyancy of the floats is so adjusted that the transparent tubes partly extend above the surface of the water. In this case, the bottom of the tubes is in the water, so the medium is cooled.

According to another preferred embodiment, the buoyancy of the floats is so adjusted that the top of the transparent tubes extends below the surface of the water by at most 50 cm, and preferably between 5 and 30 cm. This design not only ensures a good cooling of the medium in the reactor, but also guarantees that at least the outside of the transparent tubes are rinsed clean by the water, so that one can fully or partly dispense with separate cleaning. In addition, the thin layer of water above the transparent tubes produces some filtering effect of the UV rays impinging on the tubes.

According to another preferred embodiment, the buoyancy of the bioreactor can be adjusted in the floating state by setting the height and perhaps the level of the tubes, and possibly of the reactor vessel, with respect to the water level. The temperature of the mixture in the tubes can be regulated by the correct setting of the height and level of the tubes.

In a particularly advantageous embodiment, the photobioreactor is fitted with a temperature sensor in one or more tubes to measure the temperature of the mixture inside it or them, and there is also a control unit that is connected both to the temperature sensor and to the floats and serves the purpose of raising or lowering the buoyancy according to the temperature found. This makes it possible to bring the temperature of the mixture to within the region that is the most favorable for the growth of the microorganisms, which can improve the yield of the bioreactor. When the bioreactor is set up for the production of (micro)algae, the control unit is preferably used to adjust the buoyancy and so the position and/or the level of the tubes with respect to the water level in order to keep the temperature in the preferred temperature region of between 22 and 27°C.

The bioreactor is preferably such that it has a first inlet, connected to the reactor component, for the introduction of the liquid and/or the phototropic organisms, a second inlet, connected to the reactor component, for the introduction of the nutrients for the phototropic organisms, a third inlet, connected to the reactor component, for the introduction of carbon dioxide (CO_2), and an outlet, connected to the reactor component, for the removal of the mixture of liquid and the resulting phototropic organisms. The growth of the microorganisms can be stimulated by mixing the right amount of liquid, organisms, nutrients and carbon dioxide with one another. The amount of material to be introduced and the time of its introduction can be determined by a control unit using the data received from a number of sensors that measure a number of parameters that are representative of the growth of the organisms.

The said mixture is slowly moved along the reactor component by some means of displacement, such as pumps of any type, with the aid of which the mixture is conveyed through the reactor vessel and/or the tubes of the reactor component. The organisms in the reactor component can then be exposed (for example successively) to the daylight in the transparent part of the tubes, and screened from the daylight in the non-transparent part of the tubes or of the reactor vessel in order to promote the growth of the organisms.

According to another preferred embodiment, the reactor component comprises two or more tubes, and the coupling pieces between the successive tubes are made of a flexible material. The tubes can therefore move with respect to one another, so that the possible impact of wave action can be dissipated in the bioreactor. Furthermore, this arrangement prevents any material fatigue by the continuously changing forces acting on the tubes because of the wave motion. These coupling pieces can be made in such a way that the wave motion of the expanse of water is partly absorbed. This improves the stability of the bioreactor, which can have a positive effect on the efficiency of the reactor. An alternative or additional way to increase the stability of the reactor component involves varying the buoyancy of the floats in such a way that the wave motion of the expanse of water is at least partly compensated.

In another embodiment, the bioreactor comprises a collector unit placed on land, as well as a transport pipe that runs between the reactor component and the collector unit and serves the purpose of delivering the mixture from the reactor component to the collector unit, so that the mixture can be removed quickly and easily for subsequent use for example as a fuel.

According to an aspect of the present invention, a method is provided for the production of phototropic organisms, especially (micro)algae, which method comprises the following steps:

- at least the tubes of the reactor component of the bioreactor are inserted and made to float in an expanse of water, especially a lake or the sea;

- a mixture of a liquid and phototropic organisms is introduced into the bioreactor;

- the microorganisms are grown under the influence of daylight entering into the transparent tubes.

In another embodiment, the method comprises the adjustment of the buoyancy of at least the tubes of the bioreactor, especially their floats, which alters the level and/or position of the tubes with respect to the surface of the expanse of water, in order to adjust the operation of the bioreactor. By suitably adjusting the buoyancy, it is possible to achieve an optimum production of the target organism under the external conditions, such as for example the temperature of the mixture in the reactor and/or the temperature of the water outside the reactor, the intensity of sunlight and the strength of the waves.

It will be obvious to the expert that the method can also be carried out in a different order. For example, it is often the case that the bioreactor is first inserted in the water and is only filled after that.

Other advantageous methods will be specified in the dependent claims attached. The method comprises for example the measurement of the temperature of the mixture in one or more of the tubes, and the adjustment of the buoyancy of the bioreactor in accordance with the temperature value thus found. In most situations, the temperature of the mixture in the tubes is higher than the temperature of the surrounding water. In such a case, if there is a risk that the temperature in the tube might become too high, the tubes are immersed deeper in the water in order to increase the heat transfer to the water, while if there is a risk that the temperature in the tube might become too low, the tubes are displaced upwards. In another example, the buoyancy of the various floats is altered in order to change the level of the tubes with respect to the surface of the water. If this change is effected repeatedly, for example periodically, it can make for a better mixing of the liquid and the microorganisms, which in turn promotes the growth of the latter. The same aim can be achieved if the reactor is placed in an expanse of water with a certain swell. The latter can bring about changes in the level of the bioreactor, so a better mixing and hence a better growth of the microorganisms can be achieved.

Other advantages, features and details of the present invention will be explained in the following description of the preferred embodiments. In this description, reference is made to the attached drawings, where:

Figure 1 is a diagrammatic perspective view of a preferred embodiment of a floating bioreactor according to the invention;

Figure 2 is a diagrammatic cross-section of a tube of a reactor component, in the floating state; and

Figure 3 is a perspective top view of a flexible coupling piece.

Figure 1 shows a photobioreactor 1 for the production of microalgae, such as blue-green algae or green algae. Microalgae are microscopic single-cell plants that grow in a liquid medium. Growing algae make use of light and specific nutrients, mainly carbon dioxide, soluble nitrogen compounds and phosphate. Daylight is generally used in practice as the necessary light, but artificial light can be used as an alternative to daylight or in addition to it. A small amount of the microorganisms is admixed to the liquid, such as for example water, especially fresh water or sea water. The organisms do well in this aqueous medium. If microalgae are used, which can utilize the available light and nutrients extremely efficiently, the growth of these algae can be at least twice as fast and even more than 5 times as fast as the growth of conventional agricultural plants.

As mentioned above, the liquid in which the microorganisms are cultured can be fresh water or even saltwater. However, it is also quite possible to use water of a lower quality, such as for example the effluent (waste water) from a waste water treatment plant. The microalgae can remove certain nitrogen compounds and phosphate from this effluent, so they need not be eliminated in the waste water treatment plant itself. This represents a saving on the cost of waste water treatment. Furthermore, microalgae can remove certain gases, such as carbon dioxide (CO_2) and nitrogen oxides (NO_x), from flue gases. Flue gases can be for example a by-product of certain industrial processes in plants such as power stations. This by-product, which is in itself undesirable and unavoidable, can then be advantageously utilized for promoting the growth of microalgae.

The product resulting from the rapid growth of the microorganisms, which is also called biomass here, can be used for various purposes. Certain algal varieties are suitable for example for making valuable useful products, including natural colorants, unsaturated fatty acids and other bioactive substances. The biomass can be converted into biofuel, such as for example biodiesel, either directly or after the extraction of these valuable products.

The bioreactor 1 according to the invention, shown in the embodiment illustrated in Figure 1, comprises a number of elongated tubes 4, which are essentially transparent in order to allow daylight to pass through to the reactor component 2. In order to minimize the base area needed for the tubes, they are arranged in a meandering pattern. For this purpose, they are fitted with bent coupling pieces 5 at their end. The tubes 4 and the coupling pieces 5 jointly constitute a reactor component 2 of the bioreactor 1.

The tubes 4 are arranged horizontally in this example, but different orientations, such as vertical or oblique arrangements, are equally possible for them. The cross-section of the tubes can in principle have any shape, but an essentially circular or oval cross-section is preferred for them in order to be able to clean the tubes easily from the inside. This is because such tubes do not have any longitudinal edges where dirt could accumulate. The tubes can have a varying diameter, but in certain specific embodiments of the invention they have a diameter of at least 30 cm or even at least 120 cm. In the example illustrated in the drawings, their diameter is about 65 cm.

The end of the reactor component 2 is fitted with connecting elements 6, 7. One of the functions of these connecting elements 6,7 is to connect the reactor component 2 to the rest of the reactor. At the same time, the connecting elements 6,7 form part of the cleaning system. Both connecting elements 6,7 are connected to pipes 10. These pipes 10 are also connected to a feed vessel (feed barrel) 8, in other words, there is a pipe 10 running from connecting element 6 to the barrel 8, and there is also a pipe 10 running from connecting element 7 to the same barrel 8. The feed barrel 8 is not transparent, so that the algae in it are not exposed to daylight. The mixture of algae and liquid is subjected to the previously mentioned “dark phase” in the feed barrel 8.

The feed barrel 8 comprises a number of sensors (not shown), used for measuring the temperature, the electrical conductivity, the pH and the height of the mixture in the barrel. These sensors are connected to an electronic control unit 12, which uses the resulting sensor values to determine whether the algae in the feed barrel 8 need any extra nutrients and/or carbon dioxide in order to achieve a better algal growth. If extra nutrients and/or carbon dioxide are needed, the control unit 12 actuates one or more of the pumps 15-17. In the embodiment illustrated, there are three pumps, namely a pump 15 for regulating the acidity in the barrel 8, a pump 16 for regulating the amount of nutrients in the mixture, and a harvest pump 17 with which the algae are harvested. However, the number of pumps can vary in practice in order to be able to introduce either more or fewer different nutrients and/or gases and so promote the growth of the algae.

Pumps 15,16 regulate the pH of the mixture in the feed barrel 8 and the level of the nutrients, respectively. The harvest pump regulates the flow to a filter system 19, which is connected to the feed barrel 8 by a pipe. The filter system 19 is intended for harvesting the algae and comprises for example a bag filter (not shown), in which the algae are collected.

The flow of the liquid/alga mixture is regulated with the aid of the liquid pump 9, which is connected to one of the pipes 10. The liquid pump 9 can also be actuated by the control unit 12. In normal operation, the mixture is in most cases pumped in just one direction. This direction is indicated by the arrow (P_1) in the example illustrated in the drawings. The direction can of course be opposite to this in another example.

According to the invention, the bioreactor 1 is placed in water. Certain parts of the bioreactor 1 are set up on a floating pontoon 20, while others parts, such as the tubes 4 of the reactor component 2 themselves, can be made buoyant. For this purpose, the tubes 4 in the example illustrated here are fitted with a number of elongated floats 21 that ensure sufficient buoyancy and so enable the reactor component 2 to float in an expanse of water (W). The floats 20 are attached to the tubes 4 by means of bands or belts 22 and extend laterally outward from them.

The number and form of the floats 21 are chosen in such a way that the tubes 4 float in the water just below the surface. In the situation illustrated in Figure 2, the distance (a) from the top of a tube 4 of the reactor component 2 to the surface of the water 23 is between 5 and 25 cm, so that tube 4 is fully submersed. It has been found that, provided that the tube is not below the surface of the water by more than this distance (a), there is still enough light entering the tube for the phototropic organisms, and at the same time a complete cooling of it can take place.

In other embodiments, not shown here, the top of the tube 4 protrudes above the surface of the water 23, but the rest of the tube 4 stays under water. The water affects the temperature of the contents of the tube 4 of the reactor component 2 in both cases, but this effect is greater in the state shown in Figure 2. Although heat transfer from the water to the reactor component is possible in certain extreme situations, the heat transfer will in most cases occur in the opposite direction, namely from the contents of the tube to the water, so that the water exerts a cooling effect on the tube. Since there is risk of excessively rapid warming of the tube 4 when it is set up outside the water and in strong sunlight, the heat transfer has the required cooling effect on the reactor component, so that a cooling device intended specially for cooling the medium in the reactor component can be left switched off or it can be dispensed with altogether.

By varying the position of the tube 4 with respect to the surface of the water, it is also possible to apply the cooling (or warming) effect of the water at will. The position of the tube 4 can be varied for example with the aid of inflatable floats 25 filled with a gas. The buoyancy of the floats can be adjusted by altering the gas filling. For example, when the temperature sensors 26 are inserted in the tubes, the temperature of the mixture in the reactor component 2 can be determined instantaneously. The temperature sensors 26 are connected to the previously mentioned control unit 12, which is set up for example on the pontoon mentioned above. The sensors 26 transmit to the control unit 12 the appropriate electrical signals, which are representative of the indicated temperature of the medium. When the control unit 12 perceives that the indicated temperature lies outside the temperature range that has been set in advance and fed into the memory of the control unit 27 (e.g. 22-27°C), this unit adjusts the buoyancy of the inflatable floats 25. In an initial situation where the water is relatively cold, the control unit 12 will raise the buoyancy if the temperature measured is too low, and it will reduce the buoyancy if the temperature measured is too high.

To ensure that the tubes 4 can move with respect to one another also if there is a swell in the expanse of water, the coupling pieces 5 mentioned above are made in flexible form. Figure 3 shows an example of such a flexible coupling piece 5. A coupling piece 5 is formed of a cylindrical jacket 29, whose outside surface 30 and/or inside surface 31 are fitted with peripheral grooves 32 and 33, respectively. In the example illustrated here, a large number of peripheral grooves 32,33 are used next to one another, and the grooves run essentially parallel to one another. Other embodiments are also possible, for example embodiments with one or more spiral grooves. The important point is that the grooves 32,33 can ensure a greater degree of flexibility for the coupling piece 5 than would be possible without them.

The coupling piece 5 is preferably made of a plastic, for example HDPE.

The coupling pieces 5 do not only permit the movement of the tubes 4 with respect to one another, but they can also ensure an extremely small minimum radius if they - the coupling pieces 5 - are used in a bent arrangement. The resulting small radius makes it possible for the tubes 4 to run close to one another in a parallel arrangement, so that the reactor component only takes up a small space or area.

The present invention is not restricted to the preferred embodiments described here. The rights requested are set out in the following claims, but many changes, alterations and modifications are possible within the scope of these claims.

CLAIMS

1. Photobioreactor for the production of phototropic organisms, especially (micro)algae, which reactor comprises:

- at least a reactor component into which a mixture of a liquid and phototropic organisms has been or is to be introduced, where said reactor component comprises a reactor vessel and one or more tubes connected to the reactor vessel, the reactor vessel is essentially protected from daylight, and the tubes are at least partly transparent, so that daylight can penetrate the reactor component to enable the organisms to carry out their photosynthesis;

- one or more floats to ensure buoyancy for at least the tubes of the reactor component when the bioreactor is placed in an expanse of water, especially a lake or the sea.

2. Bioreactor according to claim 1, wherein the buoyancy of the floats is adjusted in such a way that the transparent tubes partly protrude from the surface of the water.

3. Bioreactor according to claim 1 or 2, wherein the buoyancy of the floats is adjusted in such a way that the top of the transparent tubes extends below the surface of the water by at most 50 cm, and preferably by between 5 and 30 cm.

4. Bioreactor according to any one of the preceding claims, wherein the buoyancy of the bioreactor can be adjusted in the floating state.

5. Bioreactor according to claim 4, comprising a temperature sensor in one or more of the tubes for measuring the temperature of the mixture present there, as well as a control unit that is connected both to the temperature sensor and to the floats in order to increase or reduce the buoyancy in accordance with the temperature measured.

6. Bioreactor according to claim 5, wherein the control unit is used for keeping the temperature within the preferred temperature range by adjusting the buoyancy and so the position of the tubes with respect to the water level.

7. Bioreactor according to any one of the preceding claims, also comprising:

- a first inlet, connected to the reactor component, for the introduction of the liquid and/or phototropic organisms;

- a second inlet, connected to the reactor component, for the introduction of nutrients for the phototropic organisms;

- a third inlet, connected to the reactor component, for the introduction of carbon dioxide (CO_2);

- an outlet, connected to the reactor component, for the removal of the mixture of the liquid and the resulting phototropic organisms.

8. Bioreactor according to claim 7, comprising means of displacement for conveying the mixture through the reactor component.

9. Bioreactor according to claim 7 or 8, comprising:

- sensors for measuring a number of parameters that are representative of the growth of the organisms;

- a control unit that is connected to the sensors and at least to one of the inlets and which is used for the introduction of the liquid, nutrients and/or carbon dioxide in order to stimulate the growth of the microorganisms, in accordance with the parameter values found.

10. Bioreactor according to any one of the preceding claims, wherein the floats are attached to the reactor component.

11. Bioreactor according to any one of the preceding claims, wherein the floats form part of the reactor component.

12. Bioreactor according to any one of the preceding claims, wherein the reactor component comprises two or more tubes, wherein the coupling pieces between the successive tubes are made of a flexible material.

13. Bioreactor according to claim 12, comprising a number of essentially parallel tubes, with bent flexible coupling pieces between them.

14. Bioreactor according to claim 12 or 13, wherein the coupling pieces are used to absorb the wave action of the expanse of water in part.

15. Bioreactor according to any one of the preceding claims, wherein the buoyancy of the floats is varied in such a way that the wave action of the expanse of water is at least partly compensated.

16. Bioreactor according to any one of the preceding claims, comprising a collecting unit placed on land, and a transport pipe that is provided between the reactor component and the collecting unit, for the transfer of the mixture from the reactor component to the collecting unit.

17. Method for the production of phototropic organisms, especially (micro)algae, with the aid of the bioreactor according to any one of the preceding claims, which method comprises:

- the placement and floating of at least the tubes of the reactor component of the bioreactor in an expanse of water, especially in a lake or the sea;
- the introduction of a mixture of a liquid and phototropic organisms into the bioreactor;
- growing the microorganisms under the influence of daylight entering into the transparent tubes.

18. Method according to claim 17, comprising the adjustment of the level and/or position of the tubes with respect to the surface of the expanse of water by adjusting the buoyancy of at least the tubes of the bioreactor, especially their floats.

19. Method according to claim 18, in which part of the tubes is made to protrude from the surface of the water.

20. Method according to any one of claims 17-19, comprising the

adjustment of the buoyancy of the bioreactor, especially its floats in order to make the transparent tubes extend below the surface of the water by at most 50 cm, and preferably by between 5 and 30 cm.

21. Method according to any one of claims 17-20, comprising the adjustment of the buoyancy of the bioreactor while it is floating in the expanse of water, in order to fix the position of the tubes and possibly the reactor vessel with respect to the water level.

22. Method according to any one of claims 17-21, comprising the measurement, in one or more of the tubes, of the temperature of the mixture present there, as well as the adjustment of the buoyancy of the bioreactor in accordance with the temperature measured.

23. Method according to claim 22, comprising the maintenance of a previously set preferred temperature region for the mixture in the tubes by adjusting the buoyancy of the bioreactor.

24. Method according to any one of claims 17-22, also comprising:

- the introduction of a liquid and/or phototropic organisms;
- the introduction of nutrients for the phototropic organisms;
- the introduction of carbon dioxide (CO_2);
- the removal of the mixture of the liquid and the resulting phototropic organisms.

25. Method according to claim 23, comprising the transport of the mixture through the transparent tubes and the non-transparent reactor vessel, to expose the organisms to daylight and to protect them from it alternately, in order to promote the growth of the organisms.

26. Method according to claim 23 or 24, comprising

- the measurement of a number parameters that are representative of the growth of the organisms;

- the introduction of a liquid, nutrients and/or carbon dioxide in accordance with the parameter values found, for stimulating the growth of the microorganisms.

27. Method according to any one of claims 17-25, comprising the adjustment of the level of the tubes with respect to the surface of the water by varying the buoyancy of the various floats.

Fig 1

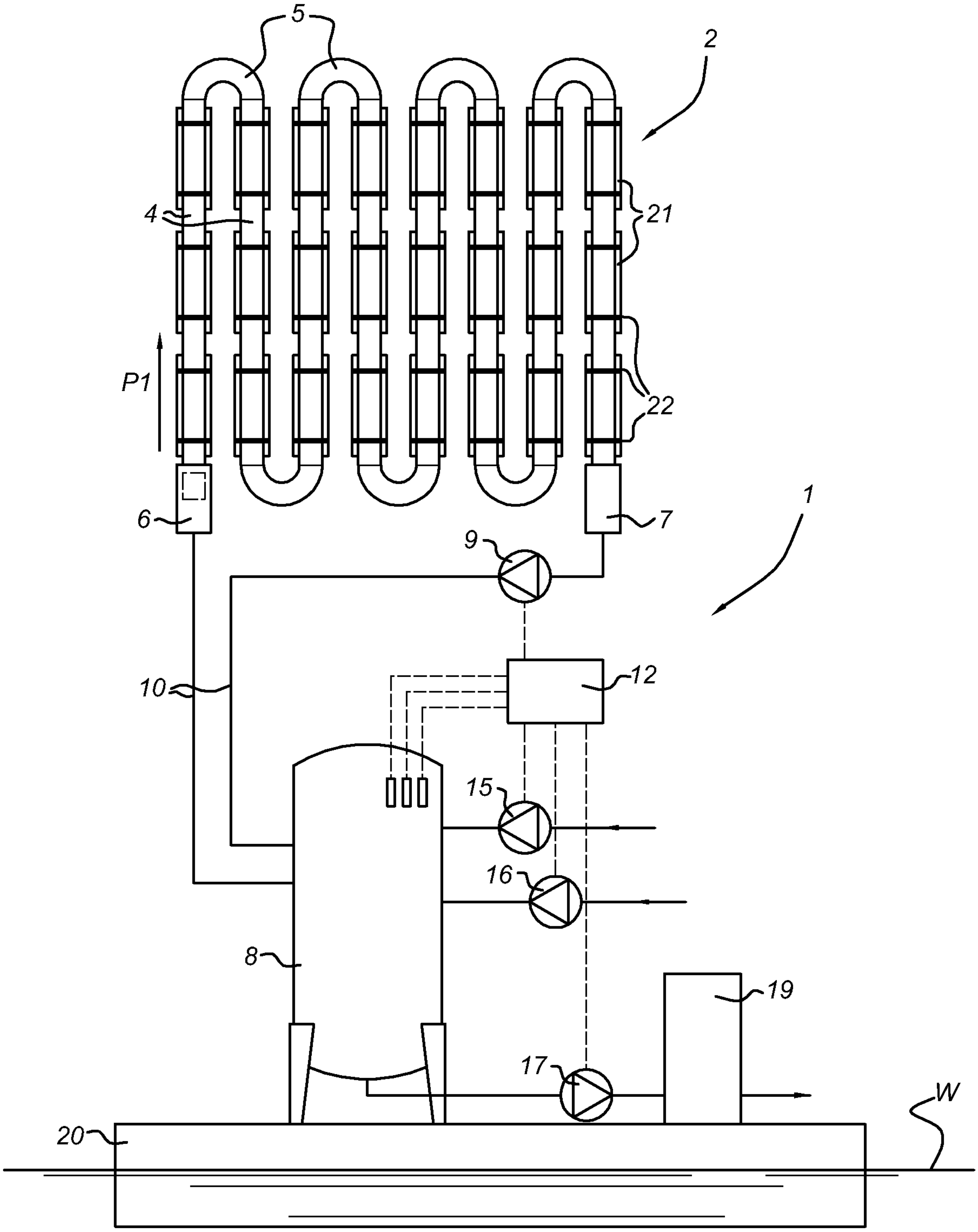

Fig 2

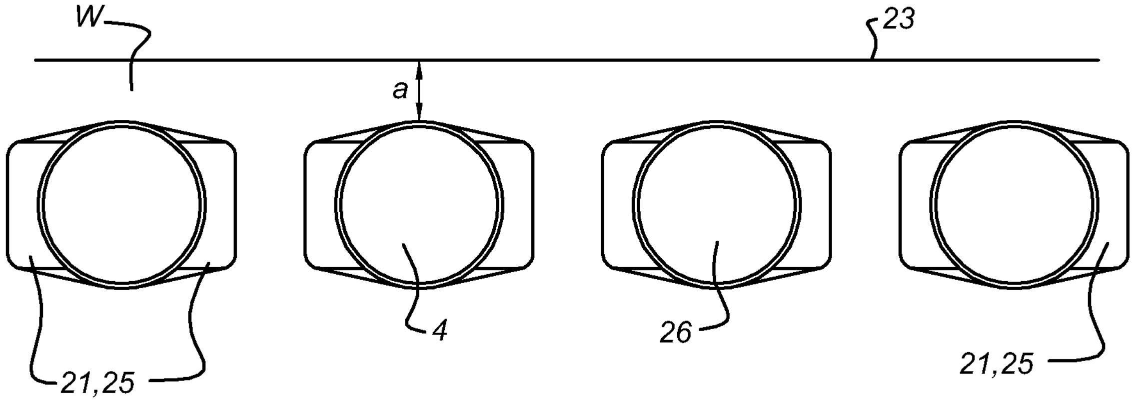

Fig 3