

PHOTOBIOREACTOR

[0001] The present application relates to a photobioreactor for growing photoautotrophs algae or microalgae. The photobioreactor is also known as a hatcher.

5 The application further relates methods of making, assembling, disassembling, installing, configuring, maintaining and using the photobioreactor.

[0002] Algae have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells. Accordingly, algae have
10 photosynthetic machinery ultimately derived from cyanobacteria that produce oxygen as a by-product of photosynthesis. Since algae can be utilised as an energy source, fertiliser, nutrition supplement, pollution control medium (e.g. carbon dioxide reduction), pigments and substance stabiliser (e.g. carrageenan), many researchers and corporations have investigated and proposed diverse types of photobioreactors
15 and hatcheries for cultivating algae or microalgae with large volumes. Productive and robust photobioreactors are desirable for industrial implementation in many parts of the world in order to deal with energy and environmental crisis.

[0003] Essential features of the invention(s) are provided by independent claims,
20 whilst important features of the invention(s) are presented by their dependent claims. The present application provides strategy of offering mixed environment cultivation in hatcheries such that growth of microalgae has been enhanced significantly. The hatcheries or hatcher is also known as photobioreactor(s).

25 [0004] The accompanying figures (Figs.) illustrate embodiments and serve to explain principles of the disclosed embodiments. It is to be understood, however, that these figures are presented for purposes of illustration only, and not for defining limits of relevant inventions.

30 [0005] Fig. 1 illustrates a first photobioreactor; and
Fig. 2 illustrates second photobioreactor.

[0006] Exemplary, non-limiting embodiments of the present application will now be described with references to the above-mentioned figures. Particularly, Fig. 1 relates

to a first embodiment of the present application, whilst Fig. 2 relates to a second embodiment of the present application.

[0007] The photobioreactor is designed to allow a multi-stage cultivation environment.

5 From an early stage to the final stage of the cultivation, a variable amount of salinity, nutrients, including inorganic salts, trace elements, and vitamins will be added. One example photobioreactor design is shown in Fig. 1. In this design, the photobioreactor has all the stages stacked on top of each other. As the initial medium is introduced to the photobioreactor by the liquid pump, liquid in the first stage together with the
10 microalgae will be “pushed” to the second stage. The time of microalgae growth can be controlled by the pumping rate. Each stage can have a different volume controlled by the residence time needed at that particular culture environment.

[0008] The multi-stage photobioreactor can also be designed in series as shown in
15 Fig. 2. Each stage can be a photobioreactor of same or different design. Similarly, the volume of the each photobioreactor is determined by the residence time of the microalgae required at each growth stage. The feed medium formula can be independently controlled at each stage of the cultivation.

20 [0009] The bioreactor can be constructed out of transparent materials, such as glass, acrylic, plastic bag, etc. to allow direct sunlight exposure. It has a multi-compartment design and each compartment may or may not has internal structures to aid circulation. Liquid medium and air/CO₂ gas will be fed from the bottom of the bioreactor. The gas and liquid will pass through the gas-liquid distributor
25 simultaneously while gas will be present in bubble form. The rising bubbles will induce an internal circulation of liquids and prevent settling of microalgae.

[0010] The number of stages is preferably between 2 to 15. The gas-liquid distributor can introduce gas and liquid mixture as well as allow the pass through of microalgae
30 from one stage to another.

[0011] The current invention is built upon the discovery that in addition to nutrients, the growth environment, such as salinity level of the medium, temperature, amount of trace elements, light intensity, etc. needs to be altered during the growth process.

Therefore, suitable culture environment can be supplied to stacked reactors or reactors in series to provide the necessary environment for the microalgae at the particular growth stage.

5 [0012] In the application, unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, non-explicitly recited elements.

10 [0013] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

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[0014] Throughout this disclosure, certain embodiments may be disclosed in a range format. The description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have
20 specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of
25 the breadth of the range.

[0015] It will be apparent that various other modifications and adaptations of the application will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the application and it is
30 intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. Photobioreactor (30, 60) for cultivating photoautotrophs (31), the photobioreactor (30, 60) comprising:
 - 5 – A first hatcher (32) for containing the photoautotrophs (31) and a first feed medium (33);
 - A second hatcher (34) for holding the photoautotrophs (31) and a second feed medium (35); and
 - 10 – A pump (36) connected to the first hatcher (32), the second hatcher (34) or both for moving the photoautotrophs (31) from the first hatcher (32) to the second hatcher (34), or vice versa.
2. Photobioreactor (30, 60) of Claim 1, wherein
The first hatcher (32) and the second hatcher (34) are sequentially connected
15 for growing the photoautotrophs (31) progressively in the two hatchers (32, 34) of different feed media (33, 35).
3. Photobioreactor (30, 60) of Claim 1 or 2, wherein
The first hatcher (32) and the second hatcher (34) are vertically stacked.
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4. Photobioreactor (30, 60) of Claim 1 or 2, wherein
The first hatcher (32) and the second hatcher (34) are horizontally aligned.
5. Photobioreactor (30, 60) of any of the preceding Claims, wherein
25 The first hatcher (32) and the second hatcher (34) have different sizes for containing varying volumes of the photoautotrophs (31).
6. Photobioreactor (30, 60) of any of the preceding Claims further comprising
A third hatcher (38) that is connected to the first hatcher (32), the second
30 hatcher (34) or both.
7. Photobioreactor (30, 60) of Claim 6, wherein
The first hatcher (32), the second hatcher (34) and the third hatcher (38) are sequentially connected.

8. Photobioreactor (30, 60) of any of the preceding Claims further comprising
A feeder (40) that is connected to the first hatcher (32), the second hatcher
(34), the third hatcher (38) or a combination of any of these hatchers (32, 34,
5 38) for providing feed medium (33, 35).
9. Photobioreactor (30, 60) of any of the preceding Claims, wherein
The feeder (40) comprises a first feeder (40) connected to the first hatcher (32)
for providing the first feed medium (33).
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10. Photobioreactor (30, 60) of Claim 8 or 9, wherein
The feeder (40) further comprises a second feeder (44) connected to the
second hatcher (32) for providing the second feed medium (35).
- 15 11. Photobioreactor (30, 60) of any of the preceding Claim 10, wherein
The feeder (40) further comprises a third feeder (46) connected to the third
hatcher (38) for providing the third feed medium (47).
12. Photobioreactor (30, 60) of any of the preceding Claims 8 to 11, wherein
20 The feeder (40) further comprises a final feeder (48) that is connected to the
pump (36) for providing a final feed medium (49).
13. Photobioreactor (30, 60) of any of the preceding Claims further comprising
A harvest channel (50) that is connected to the first hatcher (32), the second
25 hatcher (34), the third hatcher (38) or a combination of any of these hatchers
(32, 34, 38).
14. Photobioreactor (30, 60) of any of the preceding Claims further comprising
At least one sensor for monitoring nutrients in the feed media (33, 35, 47, 49),
30 growth condition of the photoautotrophs (31), or components of the
photobioreactor (30, 60).

15. Photobioreactor (30, 60) of Claim 14 further comprising
The at least one sensor comprising a chemical sensor for monitoring composition of the feed media (33, 35, 47, 49).
- 5 16. Photobioreactor (30, 60) of Claim 14 or 15 further comprising
The at least one sensor comprising a biosensor for observing growth condition of the photoautotrophs (31).
- 10 17. Photobioreactor (30, 60) of any of the preceding Claims 14 to 16, wherein
The at least one sensor is installed on the initial feeder (48), the first feeder (42), the second feeder (44), the third feeder (46), the first hatcher (32), the second hatcher (34), the third hatcher (36), the pump (36) or a combination of any of these for regulating growth or harvest of the photoautotrophs.
- 15 18. Photobioreactor (30, 60) of any of the preceding Claims 14 to 17, wherein
The at least one sensor comprises a first sensor and a second sensor connected together for providing a sensor network.
- 20 19. Cluster of photobioreactors (30, 60) comprising
The photobioreactor (30, 60) according to any of the preceding Claims, and
An open pond, a tube, a closed reactor, a horizontal photobioreactor, a vertical photobioreactor, a flat plate reactor, a fermentor-type reactor or a combination of any of these.
- 25 20. Method of cultivating microscopic algae comprising:
Providing a first hatcher (32) for cultivating photoautotrophs with a first feed medium (33);
Offering a second hatcher (34) for growing photoautotrophs (31) with a second feed medium (35); and
30 Moving the photoautotrophs, feed media (33, 35, 47, 49) or both between the first hatcher (32) and the second hatcher (34) for regulating development of the photoautotrophs.