Aeration in a Photobioreactor

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Introduction

Aeration of cultures serves to keep algae in suspension, to supply the carbon needed for plant growth and pH control, and to strip O_2 from the culture media, preventing supersaturation. The aerator system comprises any suitable equipment for:

(a) Introducing a carbon dioxide supply into the bioreactor

- Carbon dioxide can be blended with compressed air at a certain percentage (preferably from 0.1% up to 20% of CO_2) to provide carbon source for algal photosynthesis.
- In some cases, organic carbon (for example, in the form of acetic acid and/or glucose) can be added as needed into the culture medium to support algal growth.
- Any suitable source of carbon dioxide can be used, including but not limited to industrial grade, food grade, CO_2-rich flue gases emitted from power generators burning coal

(b) Efficient culture mixing

- To ensure that all algal cells come in contact with the nutrients, CO_2 and light for optimum growth.
- To ensure that produced oxygen is removed from the culture systems.
- To maintain effective turbulent flow within the photobioreactor

Optimum Aeration Condition in a Photobioreactor

Several studies have characterized the optimized aeration by carbon dioxide gas for microalgal production in a photobioreactor. Air enriched with 5% or 10% (v/v) CO_2 at rates of 0.025-1 vvm (volume of air/ medium/time) is found to be cost-effective for mass culture (Zhang et al, 2002). In flat panel photobioreactors, an optimum aeration rate of 0.05 v/v/min has been proposed sufficient to improve the mixing and mass transfer (Sierra et al, 2008).

Types of Aerator Equipments Used in a Photobioreactor

There are different types of equipments that serve aeration purposes. Most common among them include spargers or diffusers. The following details provide the features of a few types of the aerator designs employed in a photobioreactor.

Sparger is constructed with materials like biopolymers, or perforated metal or sintered glass with varying pore size based on the design and operation requirement. The sparger is connected to the base of the photobioreactor. The bioreactor is aerated by rising CO_2enriched air bubbles into the bottom of the photobioreactor via sparger assembly. The bubbles move up the entire photobioreactor column thereby getting dissolved in the culture medium.

Bubble formation process at the sparger can be separated into 2 stages:

- In the first stage, the bubble expands, while staying attached to the nozzle
- In the second stage, the buoyancy forces cause the bubble to move away from the nozzle. Bubble growth continues through a narrowing neck connecting the bubble to the nozzle. When this neck closes and the bubble detaches from the nozzle, fluid rushes in to the region of the bubble neck

There are different types of aerators equipped in a photobioreactor. The current newsletter will discuss the following most common types of aerator systems in detail:

- Porous Tube Diffuser
- Silicone Rubber Diffuser
- Sandstone and Stainless Steel Disk for Air Diffusion
- Sintered Air Diffuser
- Membrane Sparger
- Mott Sparger
- Ring or Orifice Sparger

The features and benefits of the above mentioned aerator designs are discussed in detail.

1. *Ring or Orifice sparger*

   The stirred tank and flat-plate photobioreactors is generally equipped with a ring sparger for aeration.

   Features & Benefits

- Orifice or ring sparger is essentially a perforated pipe made of a perforated metal tube, a porous ceramic material in the form of a ring. Common types include Single Orifice Sparger (SOS) and Multiple Orifice Sparger (MOS)

- When compared to the SOS for a given gas flow rate, the MOS give better gas holdup distribution in the draft tube, enhance the liquid recirculation, and reduce the fraction of the poorly mixed zones
- Ring sparger comprises a plurality of converging nozzles for air entry
- A typical ring sparger encircles the interior of the base of the bioreactor and contains a large number (several hundred) of nozzles from which air emerges.
- Gas bubbles escape from the sparger and pass upwardly until they escape from the surface of the liquid algal culture medium. A downward movement of fluid also results from the gas sparging.
- Thus, the gas sparging causes a gentle circulation and mixing of the liquid algal culture

http://www.freepatentsonline.com/4322384.html

2. *Mott sparger*

Mott spargers developed by Mott Corporation, a porous metal-product manufacturer are used for aeration in a photobioreactor during the production of algae for fuel.

Features & Benefits:

- Mott spargers introduce gases into liquids through thousands of tiny pores, creating bubbles far smaller and more numerous than with drilled pipe and other sparging methods.
- The result is greater gas/liquid contact area, which reduces the time and volume required to dissolve gas into liquid.
- Mott spargers are constructed entirely of metal, to provide long-lasting operation even in the midst of temperatures as high as 1450°F under oxidizing conditions.
- Simple, cost-effective, easy-to-install.
- From single elements to manifolded systems, Mott spargers are among the simplest, most affordable and most efficient equipment.

http://www.mottcorp.com/

3. *Membrane sparger*

Helical tubular photobioreactors employ membrane sparger for carbon dioxide biofixation.

Features & Benefits:

- A sparger useful for introducing gas into a liquid is composed of one or more gas-permeable members positioned between a gas inlet means and a gas distribution means.

- Membrane diffusers are constructed with EPDM (Ethylene propylene diene Monomer) membranes for maximum aeration efficiency and operational flexibility
- Hollow fiber membranes are uniformly fitted inside the reactor, which function as a gas sparger and produced small bubbles.
- Membrane sparger delivers small bubbles that give an efficient mass transfer of CO_2 from gas to liquid.
- The membrane sparger (elastic) operates as a linear area device, that is, the hole area appears to increase linearly with increasing pressure.
- Few photobioreactors are designed using a membrane sparger in a loop configuration resulting in a large gas/liquid interfacial area.

http://bit.ly/a8FkoP

4. *Sintered Air Diffuser*

Flat-plate and bubble-column photobioreactors employ sintered glass air diffusers to supply air/CO_2

Features & Benefits

- Bioreactors use a range of sintered glass gas diffusers with differently sized pores to disperse humidified air within the liquid biomedium
- Extremely durable and washable (reusable) air diffusing media
- Manufactured with brown Adamantine Spar (corundum/alumina) under ultra high temperature and pressure
- Applicable in Acidic or Alkaline waters (low or high pH)
- Ozone resistant

http://www.alita.com/diffuser/sintered.php

5. *Sandstone and Stainless Steel Disk for Air Diffusion*

Features & Benefits

- A unique method of aeration and mixing in which air is introduced deep into the water layer through a sandstone or stainless steel gas diffusion disk releasing numerous air bubbles are formed in the water phase.
- These numerous water coated bubbles rise through the liquid interface into the ester, carrying large amounts of water in the film
- These bubbles and droplets seem to be of such size and nature that the droplets formed do not remain emulsified when they reach the aqueous phase, but quickly coalesce and disappear into the aqueous layer.

- This method greatly magnifies the interface area, and at the proper aeration rate, half or more of the ester phase volume seems to be filled with quite rapidly settling droplets of aqueous phase

http://bit.ly/aGiuX7

6. Silicone Rubber Diffuser

Flow of air into PBR's like Fluidized Bed BioReactors (FBBR) is facilitated through fine bubble diffusers made up of silicon rubber.

Features & Benefits

- High temperature resistance.
- Low susceptibility to encrustation.
- Suitable for most of the algal species
- Less susceptible to degradation by hydrocarbons
- Designed for even distribution of air bubbles throughout the culture medium

http://www.alita.com/diffuser/siliconehose.php

7. Porous Tube Diffuser

The porous tube spargers are used in combination with helical baffle flow for aeration in photobioreactors

Features & Benefits

- The Porous Tube sparging system deliver multiple fine air bubbles to the liquid which allow efficient dispersion of oxygen.
- The sparger is generally made from HDPE (High Density PolyEthylene) and its omni-directional porous structure is an excellent feature to be used for aeration purposes.
- High-density polyethylene tubes have excellent resistance to chemicals and abrasion.
- The sparger is available fine, medium and coarse pore sizes thus providing uniform distribution of fine bubbles

http://www.alita.com/diffuser/polyethylene.php

Innovative efforts in Developing an Optimal Aerator System

Aeration is an important parameter in photobioreactor design and operation to avoid cell death and the decline in productivity. The forthcoming details provide various innovative efforts taken by researchers in designing an efficient aeration system.

Dual sparger

Dual sparging laboratory-scale photobioreactor is found to be effective for continuous production of microalgae

- The photobioreactor is designed without moving parts and equipped with two different spargers operated in dual sparging mode.
- Sufficient mixing to keep the cells in suspension is obtained by sparging with air through two single orifice spargers which deliver large bubbles and pure CO_2 at a controlled pH
- Through a perforated membrane sparger small bubbles are delivered that give an efficient mass transfer of CO_2 from gas to liquid.
- Separation of CO_2 supply from air for mixing by dual sparging increases the transfer of CO_2 from gas phase to liquid phase five fold relative to conventional sparging.
- The dual-sparger system has the potential to minimize the required aeration rates for mass transfer as well as cell damage by bubble rupture and foam problems in large scale bioreactors.

http://www.springerlink.com/content/v80g09868g423508/

Algasol Renewables Internal Aeration System

Algasol Renewables, located in Spain is a developer of a unique technology for low-cost cultivation of micro algae in a closed environment

- Algasol Renewables has investigated and tested different internal aeration systems for the aeration and stirring of the algae biomass inside the photobioreactor considering factors including economics, efficiency and scalability.
- The company has successfully launched a new photobioreactor with a fully integrated internal aeration system.
- The new internal aeration system has lowered production cost of algae oil with 10% and the results in terms of productivity and biomass density are very promising.
- Algasol Renewables achieved an average microalgal productivity of more than 60 grams per m^2 per day with an average biomass density of more than 4 g/L.
- These results are a significant milestone in the commercialization of its novel and flexible polymer photobioreactor with internal aeration system.

(September 2009)

http://www.algasolrenewables.com/en/alga2_uk

Conclusion

The aeration rate must be carefully balanced to achieve good mixing, liquid circulation and mass transfer while avoiding shear stress to the algal cells grown in a photobioreactor. Aeration must ensure the oxygen generated by photo-synthesis is removed; otherwise, it can inhibit cell growth. Thus, the above details about the design and operation of aerator systems stress the crucial role of aeration in algal cultivation using photobioreactor.

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