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Development and Performance Analysis of Low - Cost Stirred Tank and Helical Photobioreactor for Algae Production

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Abstract

Algae has become popular in the recent years for development of biofuels, nutraceuticals, aqua feed etc. Photobioreactors available for algae production have complicated design, high cost and are difficult to operate. Two simple, low cost yet efficient photobioreactors a) Stirred Tank Photobioreactor and b) Helical Photobioreactor were developed and their performance evaluation was carried out for the production of Chlorella minutissima. The performance of photobioreactors was evaluated every 24 hours by measuring the growth of algae through a) Optical Density and Transmittance Method b) Dry Weight Method through centrifuge. The highest optical density observed for helical photobioreactor was 0.264 while for stirred tank photobioreactor, it was observed to be 0.247. Lowest transmittance observed for helical photobioreactor was 48.75 % while for stirred tank photobioreactor, it was observed to be 59.21%. The average dry weight per day through centrifuge method for helical photobioreactor was found to be 9.33 $gl^{-1}d^{-1}$, while for stirred tank photobioreactor it was found to be 6.06 $gl^{-1}d^{-1}$. The study finds both photobioreactors suitable for the production of algae. Also the simplicity in design and operation makes them a suitable candidate for algae production. Growth analysis of other algae species needs to be carried out in these photobioreactors in order to upscale them for the mass production of different algae species.

Keywords: Stirred tank photobioreactor, helical photobioreactor, algae.

Introduction

The growing demand for fossil fuel, increasing pollution caused by them as well as growing demand for protein rich nutrient has forced mankind to look for a substitute that can substantially reduce our dependency on fossil fuels and food crops. Algae due to its ability to form a variety of products and being a clean and green source have been researched extensively in the last decade. Some of the advantages associated with algae are[1]: i. They can be produced using ocean and wastewater, thereby reducing fresh water use. ii. Biofuels from algae are biodegradable and relatively harmless to the environment if spilled. iii. Algae can be harvested batch-wise nearly all-year-round. iv. The doubling time is 4-6 hours in case of microalgae, providing a reliable and continuous supply of stock.

Production of algae in the open ponds is simple and cost effective, yet there are certain disadvantages like difficulty in controlling various parameters in and around the pond, bad weather, uneven light intensity, evaporative losses etc.

Photobioreactors are complex and capital intensive approaches for microalgal production[2]. Various photobioreactors have been designed and developed to overcome the disadvantages associated with open pond cultivation[3]. Based on the extensive review of photobioreactors, two photobioreactors i.e. Stirred Tank and Helical Photobioreactor were developed and their efficiency was analyzed by algal growth measurement.

Material and Methods

Stirred Tank Photobioreactor: Figure-1 shows the picture of the stirred tank photobioreactor. The culture container has dimensions as 15x9x12 inches. It consists of a stirrer for rotating the algal culture. The centre of the base of the culture container is being fitted with an aerator rod for uniform supply of air to algae.

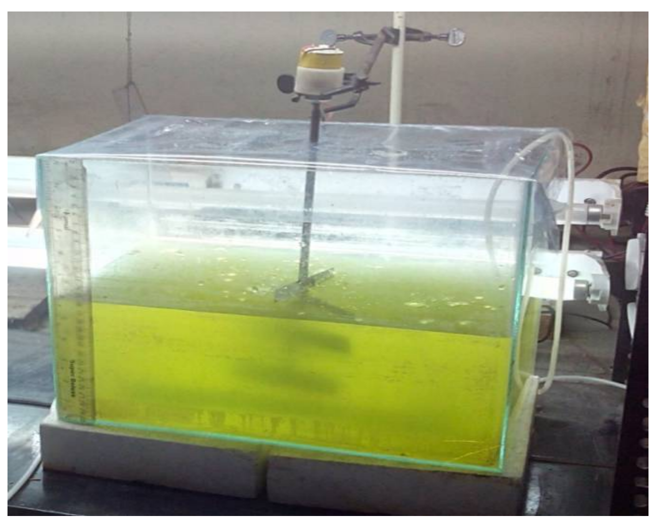

Figure-1
Stirred Tank Photobioreactor installed in laboratory for culturing algae

The aerator pipe is connected to air filter and aerator rod. The photobioreactor is sealed with a plastic cover during the production of algae to avoid contamination. Figure-1 shows the production of algae being carried out in the photobioreactor. Light for the growth of algae was supplied through florescent lights and the light intensity at the stirred tank photobioreactor was maintained at 2000 Lux. The light intensity was measured using lux meter (Mastech-MS6610). The light/dark cycle was maintained at 12h light/12h dark. The working volume of stirred tank photobioreactor was 20 Liters.

Helical Photobioreactor: Figure-2 shows the schematic of the helical photobioreactor. It consists of 6 hollow glass culture rods each having approximately 2.5 liter capacity for the production of algae connected through PVC pipes. The first and the last culture rod are connected to the reservoir as inlet and outlet point. The length of each rod is 60 inches with diameter 1.75 inch. The algae culture is being circulated into the glass rods through a submersible pump. The air is supplied to the algae through the aerator pump. Light for the growth of algae was supplied through florescent lights attached to the bioreactor frame as shown in figure-2. The average light intensity at the light harvesting area of photobioreactor was 2000 Lux. The working volume of helical photobioreactor was carried out to be 20 Liters. The algae species that was cultured in the photobioreactors was *Chlorella minutissima* obtained from Centre for Conservation and Utilization of Blue Green Algae, Indian Agricultural Research Institute, New Delhi.

Figure-2
Helical Photobioreactor installed in laboratory for culturing algae

The algae sp. *Chlorella minutissima* was grown in Modified Bold's Basal Media[4]. The pH and temperature were measured using pH meter and thermometer respectively.

Methods: The algal growth was measured by two methods: i. through optical density and transmittance method. ii. through dry weight method.

Optical Density Method: Growth of single celled organisms in suspension culture can be monitored using turbidity or light scatter measurements. As the number of cells increases the solution becomes increasingly cloudy or turbid because light passing through it is scattered by the microorganisms present. Similarly transmittance is the percentage of incident light that transmits through the sample at a particular wavelength. The optical density and transmittance of the algal culture was measured using a spectrophotometer[5] (Shimadzu UV-1601).

Dry Weight Method: 100 ml algae sample was collected and centrifuged at 10,000 rpm for 10 minutes in the centrifuge (Remi). After centrifugation, the supernatant was discarded and the pellet was dried and measured. 5 % (1 Liter) pure algal inoculum was introduced into the autoclaved Bold's Basal Media in both the photobioreactors.

Results and Discussion

The pH was measured using pH meter and was found to be between 6.9-7.4 and 6.4-7.2 for Stirred Tank and Helical photobioreactor respectively. Similarly the temperature was found to be between 22 – 24 °C and 24-25.6 °C for Stirred Tank and Helical photobioreactor respectively. Average Light intensity was maintained at 2000 lux approximately for both the photobioreactors (table-1).

Table-1
Experimental conditions during the experiment

Experimental Parameters	Stirred Tank	Helical
pH Range	6.9-7.4	6.4-7.2
Temperature Range (°C)	22-24	24-25.6
Inoculum (%)	5	5
Average Light Intensity (Lux)	2000	2000
Working Volume (L)	20	20

The optical density, transmittance and dry weight were calculated every 24 hours (table-2). The highest optical density achieved was 0.247 and 0.264 for stirred tank and helical photobioreactor respectively (figure-3). The lowest transmittance was found to be 59.21 % and 48.75 % for stirred tank and helical photobioreactor respectively (Figure- 4). The average dry weight obtained was 6.06 $gl^{-1}d^{-1}$ and 9.33 $gl^{-1}d^{-1}$ for stirred tank and helical photobioreactor respectively (Figure-5). Both the photobioreactors were found suitable for *Chlorella minutissima* as evidenced by the results obtained. The helical photobioreactor was found better for the production of *Chlorella minutissima.*

Table-2
O.D, transmittance and dry weight results obtained during the experiment

	Stirred Tank Photobioreactor	**Helical Photobioreactor**
Optical Density	0.144 - 0.255	0.186 - 0.260
Transmittance (%)	85.43 - 57.23	76.35 - 46.75
Avg. Dry Weight ($gl^{-1}d^{-1}$)	6.25	9.53

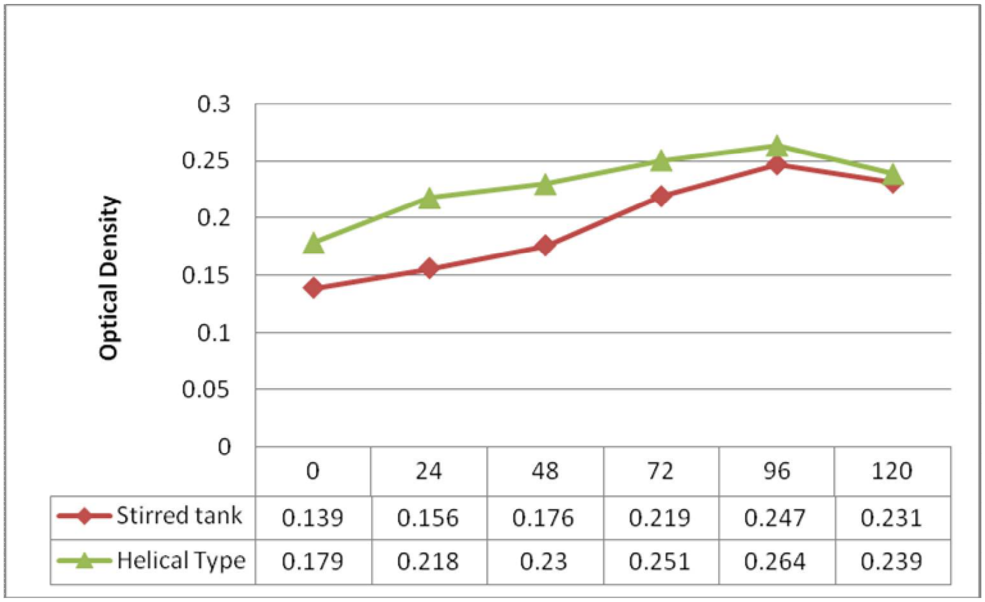

Figure-3
Comparative analysis of O.D of Stirred tank and Helical photobioreactor

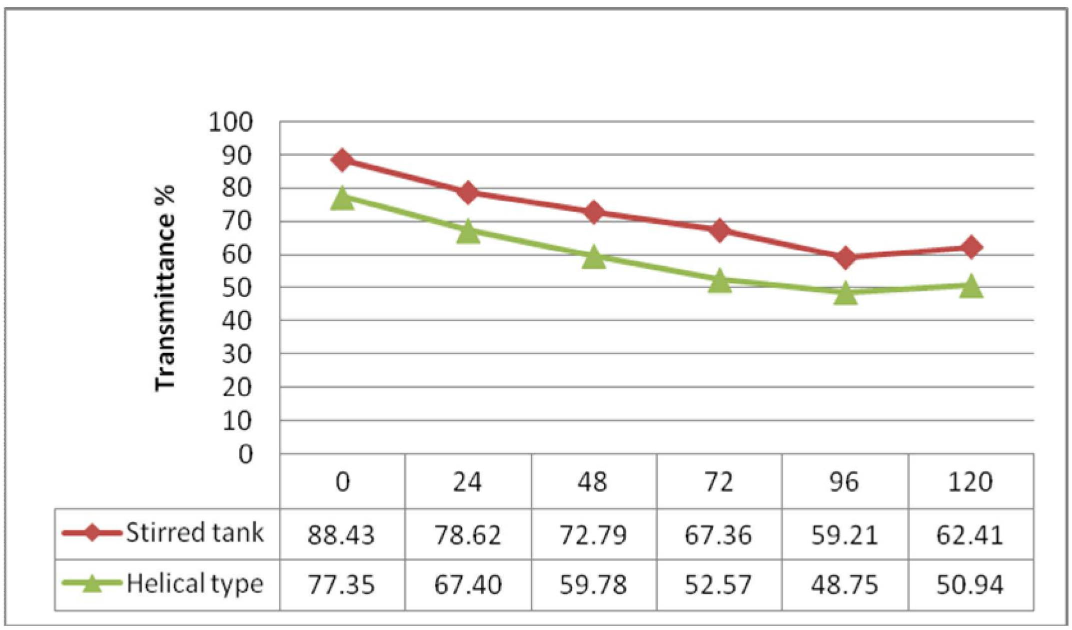

Figure-4
Comparative transmittance analysis of Stirred tank and helical photobioreactor

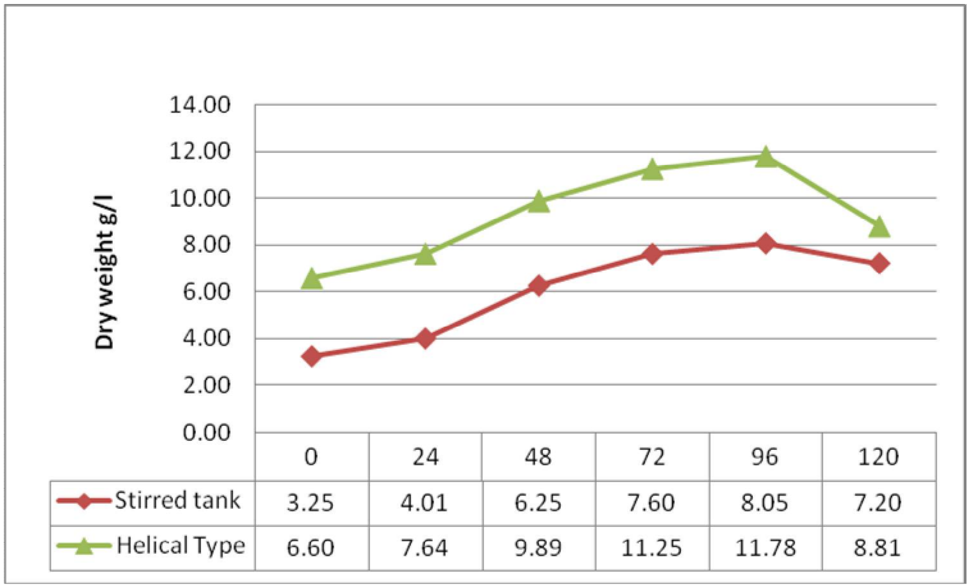

Figure-5
Comparative dry weight analysis of Stirred tank and Helical photobioreactor

Conclusion

The photobioreactors developed are simple to operate, low-cost and efficient. The comparative growth measurement of algae in these photobioreactors found helical photobioreactor better for the production of *Chlorella minutissima*. Different species of algae need to be tested for production in these photobioreactors to establish these low cost and efficient photobioreactors. Also efforts are needed to upscale these photobioreactors for the mass production of algae.

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