MATTER: International Journal of Science and Technology
ISSN 2454-5880

Uysal & Ekinci, 2019

Volume 4 Issue 3, pp. 150 - 156

Date of Publication: 30th January, 2019

DOI-https://dx.doi.org/10.20319/mijst.2019.43.150156

This paper can be cited as: Uysal, Ö., & Ekinci, K., (2019). Design of Mobile and Functional Photobioreactor. MATTER: International Journal of Science and Technology, 4(3), 150 – 156.

DESIGN OF MOBILE AND FUNCTIONAL PHOTOBIOREACTOR

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This work has been summarized from a part of the first author's doctorate's thesis.

Abstract

Recently, microalgae are used in sectors such as agriculture, food, cosmetics, animal feed, energy. Raceways are used for the most common open systems for high density cultivation when tubular photobioreactors are used for closed systems. In two decades, there have been significant developments in different photobioreactor designs for commercial scale production of alternative species in the production of commercial microalgae. There is no risk of contamination as a result of controlled cultivation in tubular photobioreactors. This allows intensive and pure cultivation.

In this study, 75 x 69 mm acrylic pipes were used for the tubular photobioreactor. Each flow path is set to 2 m. By using a 40 liter closed-loop unit while the total volume of acrylic pipes is 60 liters, total volume is designed as 100 lt. In this photobioreactor designed and prototyped, suitable conditions were established for the cultivation of different microalgae strains. The *tubular photobioreactor is made mobile and functional. In this photobioreactor, pH, optical density, biomass values are controlled.*

As a result, a mobile and functional photobioreactor has been designed to enable the cultivation of different microalgae strains for different sectors for microalgae growing. This photobioreactor is suitable for continuous, semi-continuous and continuous production.

Keywords

Photobioreactor, Tubular, Microalgae, Mobile, Functional

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1. Introduction

As the population of the world is increasing, the demand for food and energy is also increasing thereby triggering the importance of microalgae in the economy. However, the commercialization of microalgae production at large scale has not yet immature. It is evident that the production cost of microalgae should be decreased for achieving biobased material in terms of commercialization (Draaisma et al., 2013; Uysal et al., 2015; Fasaei et al., 2018).

Microalgae culture has been well developed in open ponds and canals, but only a few species can be preserved in conventional open systems that control contamination using very low alkaline or saline selective media. Open systems such as raceways or open ponds are appropriate for microalgae production. However, contamination of culture during production can cause problems such that not many species can be cultivated. Closed photobioreactors can alleviate the problems reported for open systems and allow for many species to be cultivated, of which tubular photobioreactor are the most promising for production (Molina Grima, 1999; Tredici, 1999; Uysal et al., 2016). Norsker et al. (2011) evaluated the photosynthetic efficiencies of reactors for microalgae production for raceway, horizontal tubular photobioreactors, and panel photobioreactors, 1.5, 3, and 5, respectively. However, it has been reported that the application of the same conditions such as location and the same species is required for the assessment of the different systems (Bosma et al., 2014).

Tubular photobioreactors have many advantages such as ease of circulation of culture based on non-moving parts which prevent contamination of cultures (Chisti, 1989), no harm to cell due to mechanical pumping (Chisti, 1999; Vandanjon et al., 1999) and airlift devices which allows combined work of a pump and a gas exchanger for removal of oxygen generated by photosynthesis (Camacho et al., 1999). Norsker et al. (2011) reported that oxygen should be removed since it has negative effects on photosynthesis. Sensitivity to shear differs between microalgal strains, and is dependent on multiple factors including cell size, the entity of flagella, morphology, and the presence and composition of the cell wall. Further research is needed to evaluate the physiological and environmental conditions that mitigate the sources and effects of shear stress in large-scale cultivation systems to maximize the biotechnological potential of microalgae (Wang & Lan, 2018). The level of oxygen concentrations in tubular systems can be maintained in definite limits using a degasser or stripper vessel. These systems can be oriented as horizontally and vertically. Diameters of the tubes rages from 3 to 10 cm depending on system utilized (Wang & Lan, 2018).

The construction cost of tubular photobioreactors is higher than that of open systems. Furthermore, Norsker et al. (2011) reported that investment costs of a plant based on horizontal tubular which has area of 100 ha was calculated as 0.51 M€/ha. Tubular photobioreactors are more expensive to construct than open raceway ponds, particularly vertically oriented tubular photobioreactors. Investment costs for a 100 ha horizontal tubular plant were estimated to be 0.51 M€/ha by Norsker et al, 2011. Tubular photobioreactor systems are compromised of tubes, circulation pump, and degasifier. These systems aim to provide the optimum conditions for the cultivation of microalgae. In addition, the tubes may be flat, curved, or ring-shaped (Molina et al.,2001; Pirt et al., 1983). These reactors are getting popular since they have high surface area to volume ratio thereby maintaining better lighting (García-Carvalho, et al., 2006). At the other side, since the microalgae culture should be continuously circulated they require higher energy for pumping than the other systems.

In this study, for the production of dense microalgae masses and different microalgae strains, mobile and functional reactors have been produced to provide raw materials for different sectors.

2. Materıal Method

This study was carried in Süleyman Demirel University, Faculty of Agriculture, Department of Agricultural Machinery and Technology Engineering, Biomass Laboratory. 75 x 69 mm acrylic pipes were used for the tubular photobioreactor. Each flow path is set to 2 m. By using a 40 liter closed-loop unit while the total volume of acrylic pipes is 60 liters, total volume is designed as 100 lt. The mobil and functional photobioreactor is given obtained in the study in Figure 1. In this photobioreactor designed and prototyped, suitable conditions were established for the cultivation of different microalgae strains. These strains are *Chlorella sp.*, *Chlorella vulgaris*, *Botryococcus braunii*, *Neochloris conjuncta* microalgaes.

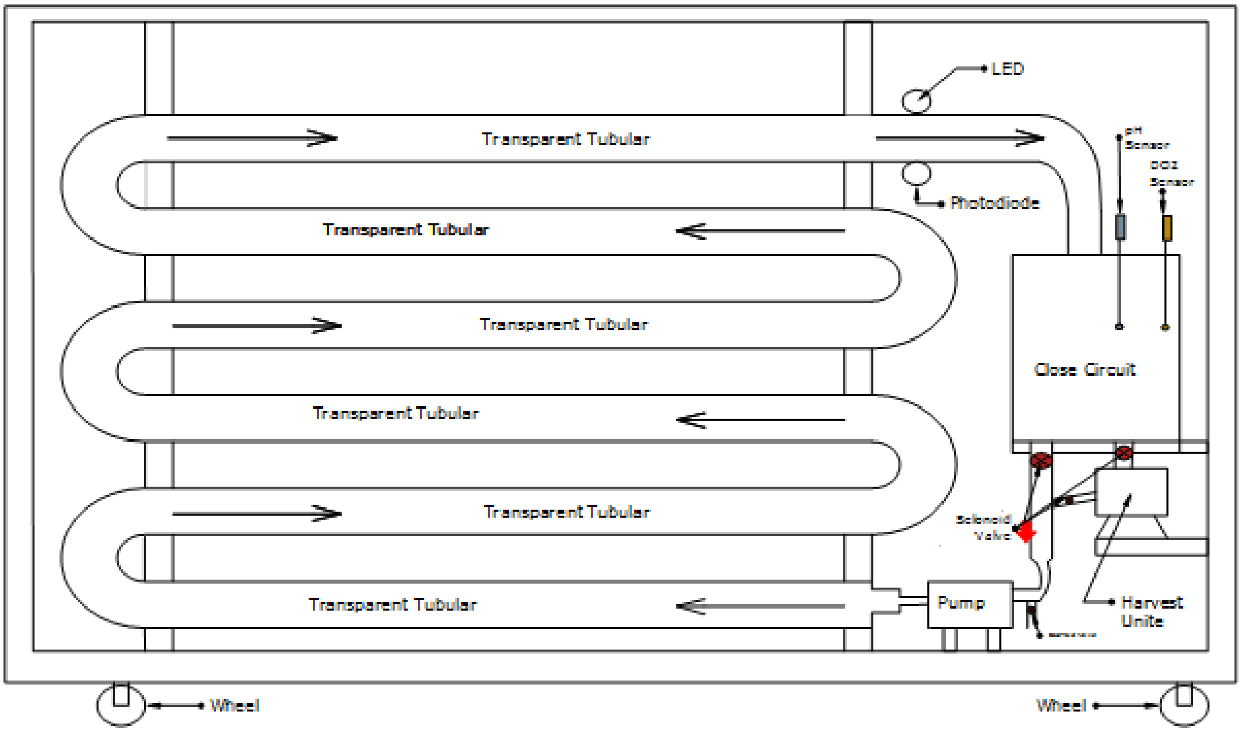

Figure 1: *Mobile and functional photobioreactor*

In order to obtain microalgae biomass from a mobile and functional photobioreactor, a unique design used in this study, firstly microalgae that volume of 20 liters of microalga with a density of 5x105 cells / ml was prepared in a 100 liter reactor in laboratory. Before microalgae was poured into the reactor, 80 liters of purified water was run and the reactor was checked for proper operation. After the control, microalgae cells were included in the system with the aid of a closed-circuit valve. A cooling system is included in the closed circuit unit to keep the microcirculated water temperature increase up to 29 ° C during the daytime operation of the reactor through transparent tubular pipelines. Also, considering the fall in night temperature, a heater is added to the closed circuit unit so that the temperature does not fall below 19° C.

The microalgae bioleaching period in the Isparta conditions where the reactor is run at this time is Chlorella sp. and Chlorella vulgaris microalgae strains for about 11 months, Botryococcus braunii and Neochloris conjuncta microalgae strains were able to 8 months and 9 months, respectively. Since the harvesting time was determined according to microalgae species in this process the tendency of the microalgae biomass to adhere to the circulation walls has been minimized in the reactor and particularly in transparent tubes. Thus, in this reactor, continuous production can be realized besides batch and semi-batch production. During continuous production, dissolved oxygen and pH values increase over time in the reactor. If the increases in these values are not controlled, the growth of microalgae slows down and even kills microalgae cells. To prevent this, the dissolved oxygen sensor and the pH sensor were installed in the closed-stage unit of the reactor. By means of these sensors, when ascending pH and dissolved oxygen (DO_2) values are determined, carbon dioxide (CO_2) is supplied into the reactor by opening a solenoid valve. As the reactor CO_2 was fed, the pH and DO_2 values were reduced to normal levels. As the pH and DO_2 values have been reduced to sufficient levels for microalgae biomass production, the CO_2 input into the reactor is cut off with the help of a selonoid valve.

To determine the harvest time of microalgae biomass, light permeability was previously calibrated with distilled water and the absorbance value was measured with LED lamp with the help of a photodiode. This photodiode is positioned at the end of the transparent tubular acrylic tube with a 40 liter dark tank inlet. Thus, utilization of microalgae biomass by daylight and circulation in the light stage has been determined by the photodiode, which has achieved sufficient density and reduced light transmittance. After that, the centrifuge harvester fixed in the harvesting unit is operated. Concentrated microalgae biomass was directed to the harvesting unit without going to the circulation pump using solenoid valves. When the microalgae pasta is collected in this harvesting unit, together with the opening of solenoid valves, separated clean water from biomass is directed to the circulation pump.

In this study, all parameters were measured by Arduino program. Microalgae grown 3 replications in photobioreactor. Every time the reactor was evacuated again. In this way, leakages, lighting measurements, harvest operations, microalgae growth parameters were measured and provided controls. The same operations are repeated in other microalgae straines.

3. Conclusion

In this mobile and functional photobioreactor, where automatic pH, optic density and oxygen measurements are taken at the same time, the final product can be obtained both in liquid form and wet biomass by adding it to the system output point at the harvesting unit. A tremendous solution is presented those in search of alternative products in sectors such as cosmetics, fertilizer, animal feed with this easy-to-use system.

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