2012 2nd International Conference on Environment Science and Biotechnology
IPCBEE vol.48 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2012. V48. 11

Effect of Flue Gas Flow Rate on Growth and Carbon Fixation Ability of *Isochrysis sp.*

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Abstract. As the concerns over global warming are increasing, many research works on carbon capture have been carried out. Among various CO_2 utilization technologies, the biological methods particularly the ones using microalgae photosynthesis, have several advantages. Apart from employing its natural process of photosynthesis, it also promotes towards an industrial symbiosis, where one's wastes becomes one's valuable input. This work makes a preliminary effort in assessing the abilities of marine microalgae, *Isochrysis sp.* in fixing carbon at different simulated flue gas flow rate. *Isochrysis sp.* was cultured upto 10days in a 10L lab-scaled photobioreactor supplied with different simulated flue gas flow rate. Illuminance is available through units of Philip's T5 type fluorescent bulb with timer-controlled. Automatic data logging of temperature, pH and dissolved O_2 was made possible through Dewetron's DEWE 43 data acquisition system. Carbon fixation ability calculation was done by comparing the gained dry weight between first and last days, taking into account the approximate biomass molecular weight in photosynthesis reaction. Results indicate that experimental run with 60% simulated flue gas exposure, pH 6, 30^0C and lighting of 1500 lux give highest fixation rate of 1.4429g/day. This result was also supported with a better growth rate characteristic at this experimental run. The finding shall be useful in utilizing this species in the future biological carbon fixation system. Further works like optimization and enhancement for downstream products can be stimulated, out of this work.

Keywords: Biological fixation, Carbon capture, Flue gas, Microalgae

1. Introduction

Emissions of carbon dioxide are predicted to increase (US DOE, 1997) due to the emissions from increased combustion of fossil fuels and have become one of the major causes of global warming. In Malaysia, electricity and energy sector contributes up to 26% to the total of nation's CO_2 emission in year 2006 (T.H. Oh, 2010), mainly due to use of fossil fuel. There are many attempts for carbon capture, including physical, chemical and biological methods (Abu Khader, 2006; J.S.Lee et al., 2003). Among these attempts, the biological method using microalgae is believed to be an effective approach for biological CO_2 fixation (Yanayi et al., 1995; Wang et al., 2008). In Malaysia, most of activities attempting to harness the values from microalgae dealt with products and purposes for nutritional diets and aquaculture food (Siew Moi Phang et al., 2005) and to a certain extent, biodiesel production (Chu Wan Loy et al., 2011) . Note that these are considered downstream products, being the resultant of photosynthesis and carbon fixation process that takes place upstream. There are almost scarce works done previously in this upstream process locally. Microalgae can utilize CO_2, efficiently, yielding three to five times more biomass per land area than typical crops and plants. The growth of microalgae can be affected by several factors such as pH, temperature, nutrient and type of gas supplied. In this research, marine microalgae, *Isochrysis sp* were isolated from local sea water and cultured to measure their carbon fixation ability using simulated flue gas. Effects of different dosing flow rate of simulated flue gas were studied on growth of *Isochysis sp.* and its carbon fixation ability.

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2. Materials and Methods

2.1. Microalgae Species

Isochrysis sp. marine microalgae species was selected for the study. This microalgae species was isolated from sea water near Janamanjung power station, Manjung, Perak.

2.2. Photobioreactor

A customized laboratory scale photobioreactor (PBR) was used in the experiment. The PBR is of bubbling column type, having double cylindrical column of 10-L each as the reactor vessel. The material of the reactor column is of polycarbonate having dimension 3 mm thick, 200 mm diameter and 800 mm high. Polycarbonate was chosen as the material due to its good impact resistance and optical properties having at least 92% transparency (Chitralekha Nag Dasgupta, et al., 2010). The PBR has the capability to vary and maintain temperature from -10^oC to 100^oC using a SASTEC ST-MP10C chiller/heater equipped with type K thermocouple. pH and dissolved oxygen were measured using Eutech Instrument sensors. Illuminance is available through five units of T5 type fluorescent bulb with timer-controlled. The growth rate of microalgae was determined by the optical density measurement at 560nm using DR/4000U spectrophotometer. The dry weight was measured by vacuum filtration using 0.2μm pore size filter paper. Simulated flue gas flow rate were varied from 0.05L/m to 0.25L/m using flow meter. Automatic data logging of temperature, pH, simulated flue gas flow rate and dissolved O_2 was made possible through a data acquisition system. Photograph of the PBR is as shown in Fig. 1.

Fig. 1: A 2x10L photobioreactor used in the experiment

2.3. Culturing conditions

Culturing was done using the $NaNO_3$ media mixed with artificial sea water. The microalgae were cultured in 10-L PBR, where the carbon fixation experiment conducted. Temperature of the culture inside the PBR was maintained at 30^0C by the chiller/heater unit. The initial optical density for both species was maintained at 0.20 abs.

2.4. Carbon fixation experiment and calculation

Isochrysis sp. species in the PBR underwent the experiment upto ten days. Regular measurements of optical density at 560 nm wavelength, and dry weight were done manually every day. Simulated flue gas containing 15% CO_2, 4% O_2, 150 ppm NO_2, 150 ppm SO_2 and N_2 (balance) was supplied to the culture. The carbon fixation calculation was adopted by taking into considerations of the ratio between the moles of CO_2 and the moles of typical molecular formula of biomass (Indra Suryata, et al. 2010; Yusuf Chisti, 2007). Thus by taking into considerations of a balanced photosynthesis formula as in Equation 1 below:

$$4CO_2 + \text{nutrient} + H_2O + \text{light} \rightarrow 4CO_{0.48}H_{1.83}N_{0.11}P_{0.01} + 3(1/2)O2 \quad (1)$$

The ratio of molecular weight of CO_2 and biomass is 1.882. This ratio is within the range of 1.81 to 2.37 (S. Van Den Hende et al, 2012), which was measured upon various elemental analysis performed on microalgae biomass. pH, temperature and illuminance value were fixed at pH 6, temperature of 30^0C and illuminance of 1500lux while simulated flue gas flow rate were varied from 20% to 100% which is 0.05L/m to 0.25L/m.

3. Results and Discussion

Growth and carbon fixation ability of *Isochrysis sp.* when supplied with simulated flue gas was investigated. As shown in Fig. 2, the amount of carbon fixed for *Isochrysis sp.* was highest in experimental run with 60% simulated flue gas exposure, pH 6, 30^0C and lighting of 1500 lux. The carbon fixed amount at these conditions was 1.4429g/day. While the lowest carbon fixation of 0.3137g/day was obtained with operating conditions of 100% simulated flue gas exposure, pH 6, 30^0C and lighting of 1500 lux. Simulated flue gas composed of 15% CO_2, 4% O_2, 150 ppm NO_2, 150 ppm SO_2, balance N_2 was selected because it approximates a typical flue gas stream from a coal-fired power plant.

Fig. 3 shows the growth rate in terms of optical density which correlates to the cell density of the microalgae and from it, run with 60% simulated flue gas exposure, pH 6, 30^0C and lighting of 1500 lux showed the highest cell growth throughout the cultivation period, as evidenced by its steeper line. This growth ability of *Isochrysis sp.* supports previous studies which reporting the enhanced growth in high CO_2 levels in flue gas system (Brock, 1978).

However, from Fig. 3 the experimental run with operating conditions of 100% simulated flue gas exposure, pH 6, 30^0C and lighting of 1500 lux, showed that the growth of *Isochrysis sp.* was completely inhibited as indicated by the steady decrease in culture absorbance. In addition, this experimental run also gave the lowest carbon fixation rate of 0.3137 d/day. With 100% of simulated flue gas exposure, the amount of gas composition delivered to the microalgae culture is increased. According to previous studies done by academician and researchers, the exposure of some gas composition in flue gas could inhibit the microalgae growth. John T. Hauck et. al (2008) reported that the higher exposure of SO_2 could provide the acidic environment needed for the microalgae growth caused by the solubility of SO_2 in aqueous solution. There are also research work claimed that NO_2 gas is another potential harmful agent to growth of biological systems.

Although the culture pH was maintained at pH6, the solubility of SO_2, NO_2 or some hydrolysis product would be higher as the flow rate increases and it may delay or inhibit the microalgae growth. With the results shown, it can be concluded that the optimization of dosing flow rate of flue gas supplied to the culture is important to set the applicable limit in order to enhance the growth of microalgae for carbon fixation.

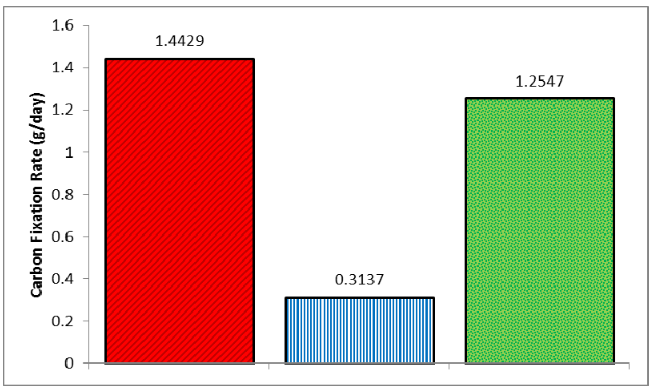

Fig. 2: Comparison of the rate of carbon fixation for 10-L PBR charged with simulated flue gas

Culture condition: 60%, pH6, 30°C, 1500lux, 100%, pH6, 30°C, 1500lux, 20%, pH 6, 30°C, 1500lux

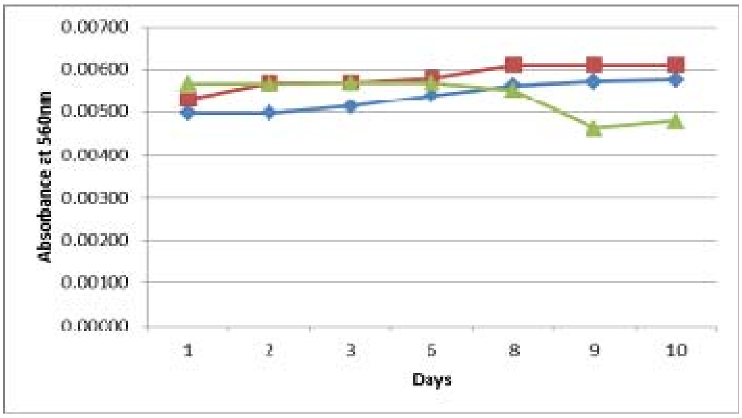

Fig. 3: Growth rate characteristic for *Isochrysis sp.* under different operating conditions

Culture condition: 60%, pH6, 30oC, 1500lux, 100%, pH6, 30oC, 1500lux, 20%, pH 6, 30oC, 1500lux

4. Conclusion

Based on the carbon fixation test on microalgae cultivation in the 10-L photobioreactor using different dosing flow rate of simulated flue gas as described in this work, it is found that *Isochrysis sp.* can fix the CO_2 better in a culture condition having 0.15 L/m of simulated gas, pH6, 30^0C and illuminance of 1500lux. These results were further strengthened by the species' steeper growth rate curve. This work strengthen the need to identify optimized culture conditions to enable maximum carbon fixation can take place. Further work could involve the optimization of other culture parameters, like illuminance level, pH, culture density and temperatures, in obtaining highest CO_2 fixation rate. The effects of other components of flue gas system and an efficient engineering design should also be studied for scale up of the pilot.

5. Acknowledgements

The authors wish to thank and appreciate the supports and co-operations of TNBR's Technical Board Committee, TNBR's Management, and Mohd Asyraf Mohd Azmir Pang, towards making this work a success.

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