FINAL REPORT

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A STUDY OF THE EFFECT OF ILLUMINATION AND TEMPERATURE ON LOCAL MICROALGAE PRODUCTIVITY IN A FLAT PLATE FIBREGLASS CONTINUOUS OUTDOOR PHOTOBIOREACTOR

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1. RESEARCH SINOPSIS

Presently microalgae is considered as an alternative biodiesel source and have been cultivated in large scale for commercial use. However, there is lack of efficient systems for mass cultivation of microalgae. In this study, a scaled up 280 L flat panel airlift photobioreactor (FP-ALPBR), based on previous work by Issarapayup and co-workers (Issarapayup, Powtongsook, & Pavasant, 2009), was designed and constructed fiberglass as an alternative system for the large scale outdoor cultivation of microalgae in Malaysia. A local north Borneon strain of *Chlorella sp.* was used to assess the growth productivity. The 280 L FP-ALPBR was capable of giving cell productivity of 2.63×10^5 cells ml^{-1} d^{-1}, maximum cell density of 6.01×10^6 cells ml^{-1} and specific growth rate of 0.15 day^{-1}. The performance of this photobioreactor was compared with the 17 L FP-ALPBR and 90 L FP-ALPBR of the same design. The 280 L FP-ALPBR gave a better performance in terms of maximum cell density, but as expected for large scale it resulted in a considerable decrease in specific growth. This photobioreactor was found to produce a larger harvesting volume and cell density but could not compare in growth rate produced by the smaller 17 L FP-ALPBR and the 90 L FP–ALPBR.

2. SINOPSOIS KAJIAN

Mikroalga adalah dianggap sebagai sumber alternatif untuk biodiesel dan telah dikultur dalam skala yang besar bagi penghasilan sebagai komersil. Walau bagaimanapun, cara ini tidak berkesan disebabkan oleh sistem yang kurang cekap iaitu menggunakan tenaga solar yang berkesan untuk pengkulturan mikroalga secara besar-besaran. Dalam kajian ini, fotobioreaktor yang berskala 280 L yang berjenis panel rata dan udara pengangkutan (FP-ALPBR), berdasarkan kerja sebelumnya yang dijalankan oleh Issarapayup dan rakan sekerja [1]. Dalam penyelidikan ini fiberglass telah digunakan sebagai bahan konstruksi (FP-ALPBR) sebagai sistem alternatif untuk pengkulturan luar bilik secara skala pilot mikroalga di Malaysia. Chlorella sp. merupakan sejenis species tempatan Borneo Utara yang digunakan untuk menilai pertumbuhan produktiviti. 280L FP-ALPBR mampu memberikan produktiviti sel sebanyak 2.63 × 105 sel ml-1 d-1, ketumpatan sel maksimum 6.01 × 106 sel ml-1 dan kadar pertumbuhan spesifik 0.15 hari-1. Prestasi fotobioreaktor ini telah dibandingkan dengan 17 L FP-ALPBR dan 90 L FP-ALPBR yang mempunyai reka bentuk yang sama. 280 L FP-ALPBR memberikan prestasi yang lebih baik dalam segi ketumpatan sel maksimum, tetapi seperti yang diharapkan untuk berskala besar, ia menyebabkan penurunan besar dalam pertumbuhan spesifik. Fotobioreaktor ini adalah didapati menghasilkan isipadu penuaian yang lebih besar dan kepadatan sel tetapi keadaan ini tidak boleh membandingkan kadar pertumbuhan yang dihasilkan oleh isipadu kecil seperti 17L FP-ALPBR dan 90 L FP-ALPBR.

There are several types of photobioreactors available, such as tubular, flat plate and column photobioreactors. Table I shows the advantages and limitations of these photobioreactors (Brennan & Owende, 2010). Reference (Eriksen, 2008) suggested that vertical tubular-type photobioreactors, such as bubble and air-lift photobioreactors, have always been assumed to produce the most efficient mixing, good light utilisation and the best volumetric gas transfer. These are criterias that need to be considered in a high density mass cultivation of microalgae in a photobioreactor. The air lift system produces good mixing within the photobioreactors which could improve light utilization, providing the flash light effect of microalgal photosynthesis (Barbosa, Janssen, Ham, Tramper, & Wijffels, 2002).

TABLE I. ADVANTAGES AND LIMITATIONS OF PHOTOBIOREACTORS

Production system	Advantages	Limitations
Tubular photobioreactor	Large illumination surface area	Some degree of wall growth
	Suitable for outdoor cultures	Fouling
	Relatively cheap	Requires large land space
	Good biomass productivities	Gradients of pH, dissolved oxygen and CO_2 along the tubes
Flat plate photobioreactor	High biomass productivities	Difficult scale-up
	Easy to sterilise	Difficult temperature control
	Low oxygen build-up	Small degree of hydrodynamic stress
	Readily tempered	Some degree of wall growth
	Good light path	
	Large illumination surface area	
	Suitable for outdoor cultures	
Column Photobioreactor	Compact	Small illumination area
	High mass transfer	Expensive compared to open pond
	Low energy consumption	Shear stress
	Good mixing with low shear stress	Sophisticated construction
	Easy to sterilise	
	Reduced photo inhibition and photo oxidation	

Source: (Brennan & Owende, 2010)

From this point of view, inclined tubular photobioreactors is promising except that it is limited by the high oxygen hold up within the system. A flat-plate photobioreactor has low oxygen build-up, as well as good for outdoor cultivation, good light path, high biomass productivity, and large illumination surface area. However, it is difficult to scale up this design. On the other hand, photobioreactors such as bubble-column, airlift, and stirred tank have good scalability. However, they have low illumination surfaces area which limits the efficiency of outdoor photobioreactors (Ugwu C.U., Aoyagi, & Uchiyama, 2010). Reference (Mansa & Lim, 2010) recommended the vertical flat plate photobioreactor because of its low oxygen hold up compared to tubular photobioreactor and it has high illumination area compared to column photobioreactor. The advantages of an air lift system would assist in reduction of the fouling as the cultivation media would be in constant flow and mixing would be encouraged by the bubbles.

The scalability of the flat plate photobioreactor is a big limitation due to the construction material. It is costly to hold up a large volume of water in a flat plate using thick glass material. Whereas some material like polymethyl methyl acrylate PMMA deteriorates under constant exposure to outdoors conditions. The type of material used for the photo-stage is very important for an ideal photobioreactor construction. Materials such as plastic or glass sheets, collapsible or rigid tubes, with low toxicity, have high transparency, high mechanical strength, high durability, chemical stability and low cost (Richmond, 2007) are the most suitable for microalgae cultivation. The ease of cleaning and reduction of the light transmittance after outdoor exposure are practical issues to consider. The use of fiberglass was proposed as the photobioreactor construction material. Fiberglass is made from plastic and glass fibers. It has high mechanical strength, easily molded, easily cleaned, robust, high durability, chemically stable, less brittle than glass and low cost. It is interesting to note that the light transmittance is low (i.e. 83.6%) compared to glass (95%) or polymethyl methyl acrylate PMMA (92%). Presently the effect of outdoor exposure on light transmittance reduction is unknowned for fiberglass.

4. OBJECTIVES OF THE PROJECT

The main objective of this research is to design a pilot scale of flat plate airlift-photobioreactor FP-ALPBR for mass cultivation of microalgae. Results obtained will be compared to the previous work by (Issarapayup, Powtongsook, & Pavasant, 2009).