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Raceway Pond Design for Microalgae culture for Biodiesel

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Microalgae culture is a potential source of biodiesel and one of the best alternatives as raw material for biodiesel production. The first objective of this work is the pilot plant design for microalgae culture of high oil content species. The design was inspired by raceway large-scale culture. Although this kind of culture is usually in outdoor ponds, the pilot plant is an indoor raceway pond, therefore, it was necessary to design the lighting system and, also, the stirring system. The designed device was tested with Isochrysis Galbana clon T-Iso semi-continuous culture. Finally, microalgae oil was extracted and this oil was suitable for biodiesel production.

1. Introduction

Nowadays petroleum sourced fuels consumption is unsustainable, therefore it is unavoidable the development of renewable transport fuels for environmental and economic sustainability. On the one hand, a carbon neutral alternative to fossil fuels is biodiesel, which is produced from waste cooking oil, animal fat and basically oil crops, although the current production can satisfy only a really small fraction of the transport fuel demand.

On the other hand, the oil crops for biodiesel production take part in agri-food industry, increasing food crops price. For this reason, microalgae are the best alternative as raw material for biodiesel production. Oil content in microalgae is many times upper than traditional oil crops, thus microalgae culture is a potential source of biodiesel (Chisti, 2007).

Microalgae are very similar to the others plants, they use sunlight and nutrients for growing. Algae culture knowledge is well developed because they were cultivated since 1940's and there are a lot of commercial applications of microalgae, therefore the growing parameters are well researched (Spolaore et al., 2005).

There are two methods of large-scale production of microalgae: raceway pond and tubular photobioreactor (Janssen et al., 2003). On the one hand, closed photo-bioreactors have had more significance, because they allow a better control of the cultivation conditions than open systems. Therefore, closed photobioreactors have some advantage: higher biomass productivities are obtained and contamination troubles are

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controlled. On the other hand, open ponds have easier operation and construction, although they are limited in the control of culture conditions. It is the best system for mass cultivation of microalgae, moreover, raceway ponds are the most profitable (Ugwu et al., 2008). For that reason, in this work the design of the pilot plant was based on the second method, because, authors consider that it is more important high production than high productivity.

The designed device was tested with Isochrysis Galbana clon T-Iso semi-continuous culture and microalgae oil was extracted for determining their suitability for biodiesel production.

2. Design

2.1. Geometry

The raceway ponds are extensive farming systems that require large sunny tracts, so these are plants that occupy large areas. Our plant is to laboratory-scale, therefore, a little surface will be representative of the large-scale culture. The pilot plant consists in two ponds and the pond size is shown in the figures 1 and 2. The illuminated area of culture is 0.525 m^2.

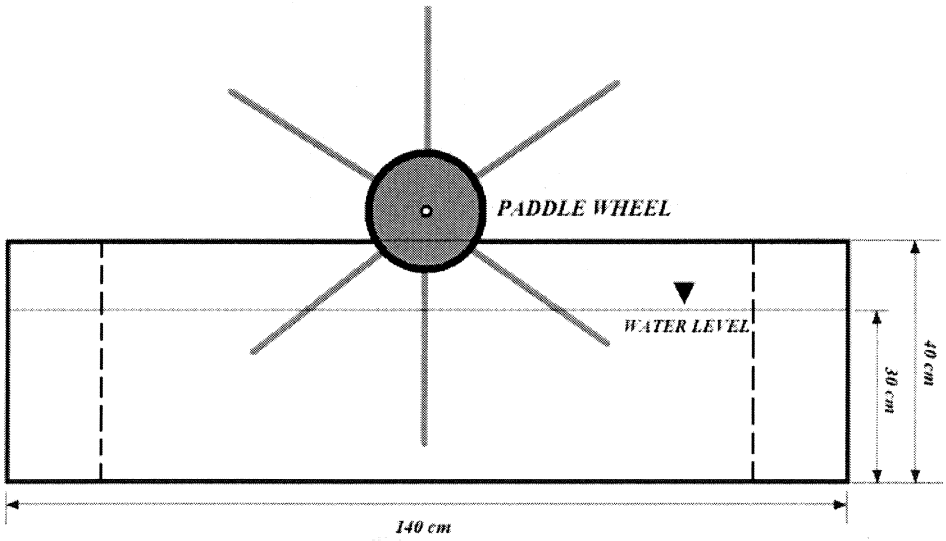

Figure 1: Culture pond side view.

To set the depth, it is important to avoid the shadowing effect where the microalgae cells do not allow to get into the culture, then the cells down water column are not well illuminated (Quiang et al., 1996).

For that reason, it was chosen the depth (0.3 m) according to other authors (Garcia et al., 2000). Finally, the volume of each pond is about 100 L.

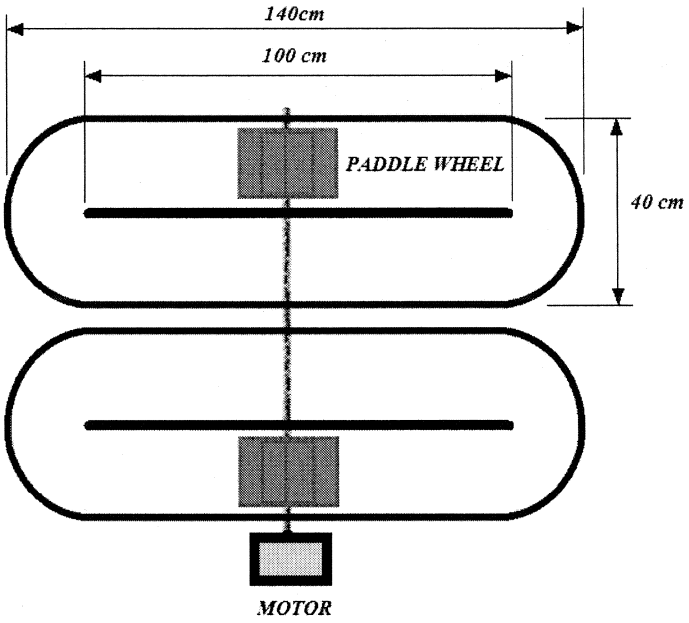

Figure 2: Culture pond top view.

2.2. Lighting System

The lighting system objective is to simulate the sunlight in outdoor cultures. For this reason, the lamps must offer intensity, colour temperature and CRI (Colour Redding Index) similar to daylight. Lastly, the lighting system was designed for cultures were maintained with 1.2 ± 0.2 klux light intensity under 16:8 light-dark cycle (Dayananda et al., 2006).

2.3. Stirring System

The ponds require a constant stirring, for mixing and recirculation of the culture, because it is necessary to avoid concentration gradients. Stirring system provides light homogenously to the microalgae. This way is other solution to the shadowing effect, because the stirring causes movement into the all water column. The stirring is produced by paddle wheels, one per pond; both wheels are joined to the same main axle (Figure 3).

3. Construction

The plant was made following the design. The ponds were made of methyl methacrylate, it is a transparent plastic material of 1 cm wide, easy to work. The ponds were assembled over one steel structure. The lighting system was situated over the ponds in the structure. This system consists of two lamps with daylight-type fluorescent lights (Philips, 36W, TLD 965). The lighting system also has a timer to control light-dark cycle.

The other system adapted in the steel structure is the stirring system. It consists of two paddle wheels made of methyl methacrylate and fixed to the same axle. The axle is leant on two bearings in the structure. The movement is produced by an electric motor (37 W, 12 V and 5 A). The speed is controlled, from 10 to 62 rpm. The movement is transmitted from the motor to axle by a drive belt.
Out of pilot plant, in the culture tests, it was used a carbon dioxide cylinder like supply of CO_2. The gas is supplied by plastic pipes with a pressure regulator.

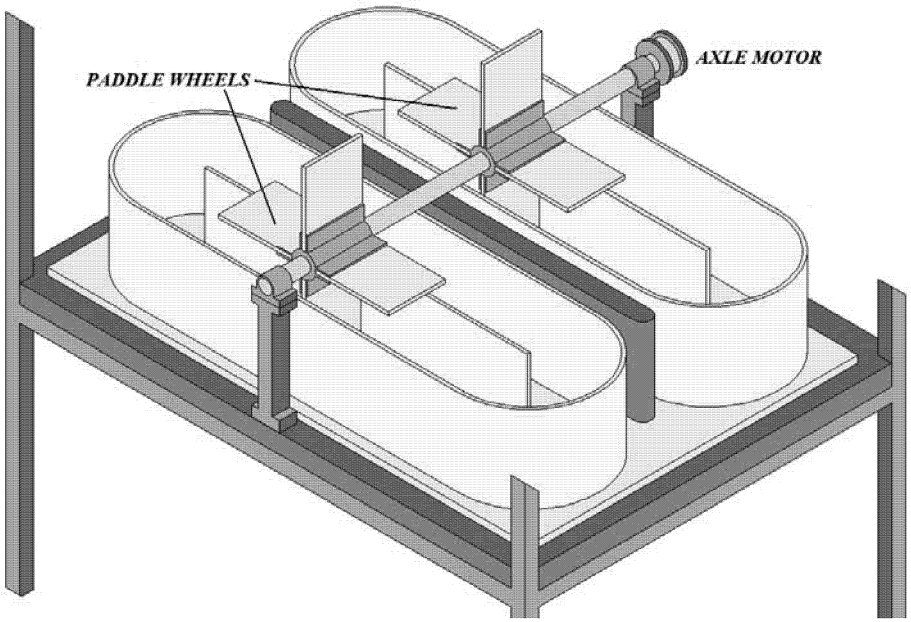

Figure 3: Design drawing of stirring system.

4. Operation

The designed device was tested in Isochrysis Galbana clon T-Iso semi-continuous culture. It was cultivated in the medium Guillard F/2 (Guillard et al., 1962). The pilot plant has not temperature control system; therefore, the culture temperature will be laboratory temperature.
For this reason, it was chosen Isochrysis Galbana clon T-Iso, because the optimal temperature of this species is about 18-19 ºC (Sanchez et al., 2000). The other reasons for this choice were good oil content and easy obtaining strain in our region, provided by the Toralla Marine Sciences Station (ECIMAT). In the figure 4, it can be observed the operating pilot plant.

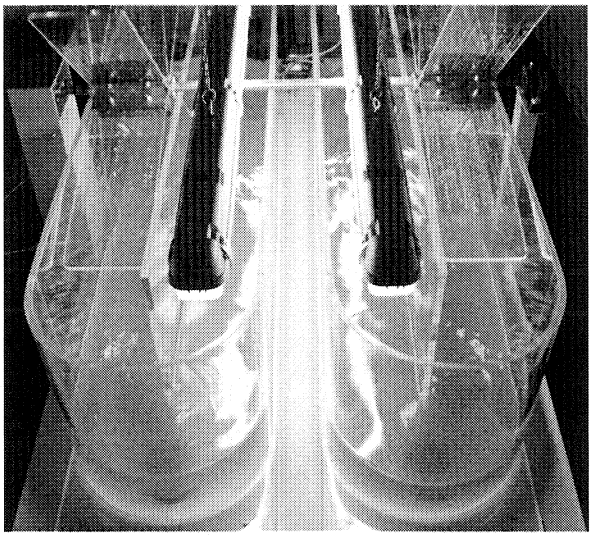

Figure 4: Image of operating plant.

The test consisted in 24 days of culture, divided in three harvests in different conditions, starting from 10 L inoculums. The objective of these tests was to check the illumination and stirring systems, and to know the influence of the supply of CO_2 and the stirring. During the culture, it was monitored the pH, the temperature and the absorbance.
The culture in the plant was possible, being suitable illumination and stirring systems. From 10 L of initial inoculums ($1.25 \cdot 10^7$ cells/mL), it was produced 115 L of total harvest ($7 \cdot 10^6$ cells/mL), after 23 days. Comparing the three harvests in different conditions, it was can observed that the culture improved with supply of CO_2 and continuous stirring.
The culture was harvested and the microalgal biomass was recovered by three sequential unit operations: flocculation with aluminium chloride ($AlCl_3$), vacuum filtration and drying. After harvesting, it was separated the microalgal biomass, being the plant productivity 0.305 g/L. Finally, microalgae oil was extracted, being the Isochrysis Galbana oil content in the culture 15.3%, therefore, the oil productivity is 0.047 g/L. Others oil microalgae contents are higher (Chisti, 2007), up to 75%, increasing the oil productivity to 0.230 g/L.
Finally, the oil was transesterificated at 62 °C for 3 h in a reactor in presence of methanol (12:1 methanol to oil molar ratio) and sodium hydroxide (1% g NaOH/g oil). The obtained conversion was 91 %. Then, this oil was suitable for biodiesel production by alkaline transesterification.

6. Conclusions

In this work, it was designed a pilot plant for microalgae culture, using the open raceway pond like cultivation system. After studying different parameters of culture, special attention is given to illumination and stirring systems. Moreover, it was

calculated the pilot plant productivity; therefore, with this value and the microalgae oil content, it is possible measure large-scale plant of microalgae culture.

Isochrysis Galbana culture was suitable in plant conditions, being 15.3 % the oil content obtained. The pilot plant is also suitable for other species with higher oil contents, being larger the oil productivity and, therefore, higher biodiesel production.

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