BIODIESEL PRODUCTION FROM MICROALGAE

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1. ABSTRACT

Biodiesel production from algae is a promising technique. Microalgae have the potential to produce 5,000 – 15,000 gallons of biodiesel per acre per year. However, there are challenges. These include high yield of algae biomass with high lipid content and the effective technique to harvest the grown algae, extract the algal oil and transesterify the oil to biodiesel.

We have designed a new tubular photo-bioreactor (TPBR) to achieve a high yield of 1g of algal biomass per liter of medium, with a lipid content of 12.8%. We are also testing an in situ technique that would combine transesterification and oil extraction into one step. This paper reports our progress.

2. INTRODUCTION

Petro-diesel fuel has been used as a source of energy since its discovery in early 6th century. Reserves of petroleum have been extracted since then and these reserves were and still are not renewable. Increasing fuel demand worldwide, rapid rise of crude oil price, limited reserve and its effect on environment push scientists to look for a clean and renewable fuel in replacement of petroleum based fuel. Biodiesel has been loomed as a potential replacement for petro-fuel.

2.1 Background:

Biodiesel is a group of esters produced by a transesterification reaction between fatty acids and an alcohol in presence of catalyst. Fatty acids (FA) used in biodiesel production come from animal fat or vegetable oil

One of the biggest challenges in biodiesel production is the availability of feed-stock. Thus far, United States of America, South East Asia, Europe and South America produce biodiesel from vegetable oil extracted from food crops such as corn, canola, soybeans, palm, etc… There is already an amplifying rejection on food crops for bio-fuel. The United Nations (UN), for instance, is expressing strong disapproval of using food crops for bio-fuel, which they believe to be the key in foods shortage and price increase, although none of these crops could produce enough oil to be converted to biodiesel, able to cover worldwide demand.

The US alone consumes about 70 billion gallons of diesel per year, which cannot be met with oil from corn, soybean nor canola, which yield nearly 50, 60 and 90 gallons of biodiesel per year per acre respectively. On the other hand, microalgae have the potential to produce 5000 to 15000 gallons of biodiesel per year per acre in open pond at optimum conditions using the right strain [6]. Obviously, biodiesel form algae could effectively replace petro-diesel.

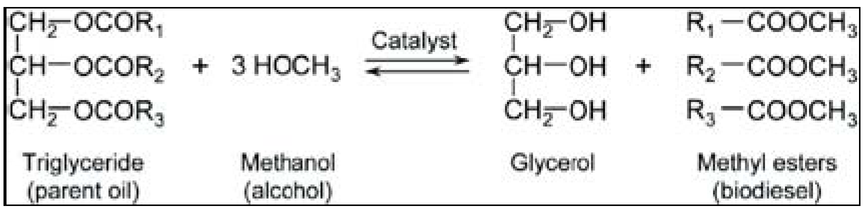
Microalgae or microscopic algae are microorganisms that convert photon from a source of light, water and carbon dioxide to algal biomass through photosynthesis[3]. Microalgae culture is similar to any eukaryote cell culture. It grows in three main phases: lag, exponential and stationary [9].

Traditionally algae are grown in open ponds. This raises several concerns such as difficulties to control growth conditions and contamination risks. Algae in open ponds are exposed to open air, with risk of being contaminated by unknown bacteria, viruses and other microorganism capable of refraining normal culture growth. In addition, mixing in open pond is challenging resulting in light deficiency, and heterogeneous medium capable of refraining normal culture growth as well. Nonetheless, close ponds (photo-bioreactors) mitigate fluid culture contamination, and enhance the control of algal growth parameters such as light penetration, homogeneous medium, and easy carbon dioxide input. Obviously, photo-bioreactors use less space with high yield in algal biomass production, although it faces excessive manufacturing and maintenance cost.

2.2 Biodiesel production

Biodiesel molecules are mixture of fatty acids methyl esters (FAMEs) produced usually from transesterification reaction between triglycerides esters (vegetable oil or animal fat) and alcohol (methanol) in presence of alkalis such as potassium hydroxide or sodium hydroxide as catalyst. During transesterification process, each mole of triglyceride is converted into a mole of fatty acids methyl esters (FAMEs) using three moles of methanol as shown in figure 1

Figure 1: tranesterification of oil into biodiesel[1]



Biodiesel can be used as a pure fuel (100%) in any engine running with petro-diesel or blended with petro-diesel at different proportion such as B20, B50 and B80 representing respectively 1:5, 1:2 and 4:5 biodiesel/petro-diesel in volume.
Production process consists in two steps: 1-solvent extraction of oil from vegetable crops or from microalgae biomass, 2- transesterification of vegetable oil into biodiesel using alcohol. This process consumes significant amount of solvent and energy for oil extraction and its transesterification resulting in high price of crude biodiesel. One way of reducing production cost would be to integrate the two-step process into one, which is our planned: in situ transesterification.

3. PROJECT GROALS

Based on the above discussion, the goals of our research are to determine a suitable algal strain and its growth conditions for optimum oil production, to design a photo-bioreactor for high yield algal biomass production. It also establishes a technique for optimum harvesting of grown algae and an economic optimum of post-harvest processing by in-situ transesterification.

4. METHODS AND PROCEDURES

4.1 Determination of suitable algal strain

Seven algae strains were selected and screened for fast growth and high oil content. Each algal was grown in a two-liter clear glass flask containing medium. Each flask was exposed to light from fluorescent lamps. Air was provided to the flask to homogenize the medium and supply carbon dioxide for photosynthesis process.
The rate of algal growth and oil content were measured in order to select the algal with high growth rate and oil content. Algal concentration was monitored more often by measuring the culture turbidity and/or cell count. Similarly, algal oil content was monitored at the same frequency by adding Nile red dye to algal solution sample. The Nile red would stain oil in the algae; one strain oil has a characteristic of fluorescence that is measured using a spectrofluorometer[11]. Over three weeks, termed strain A out of seven showed a high growth rate and less risk of contamination. Strain A has been selected for the rest of the study.

In order to reach an optimum growth rate and optimum oil content, the effect of pH on algal growth was examined. Algae were harvested in two media at different pH: neutral and pH 9. Once again, the growth rate of algae and their oil content were evaluated by measuring algae concentration and oil content as aforementioned.

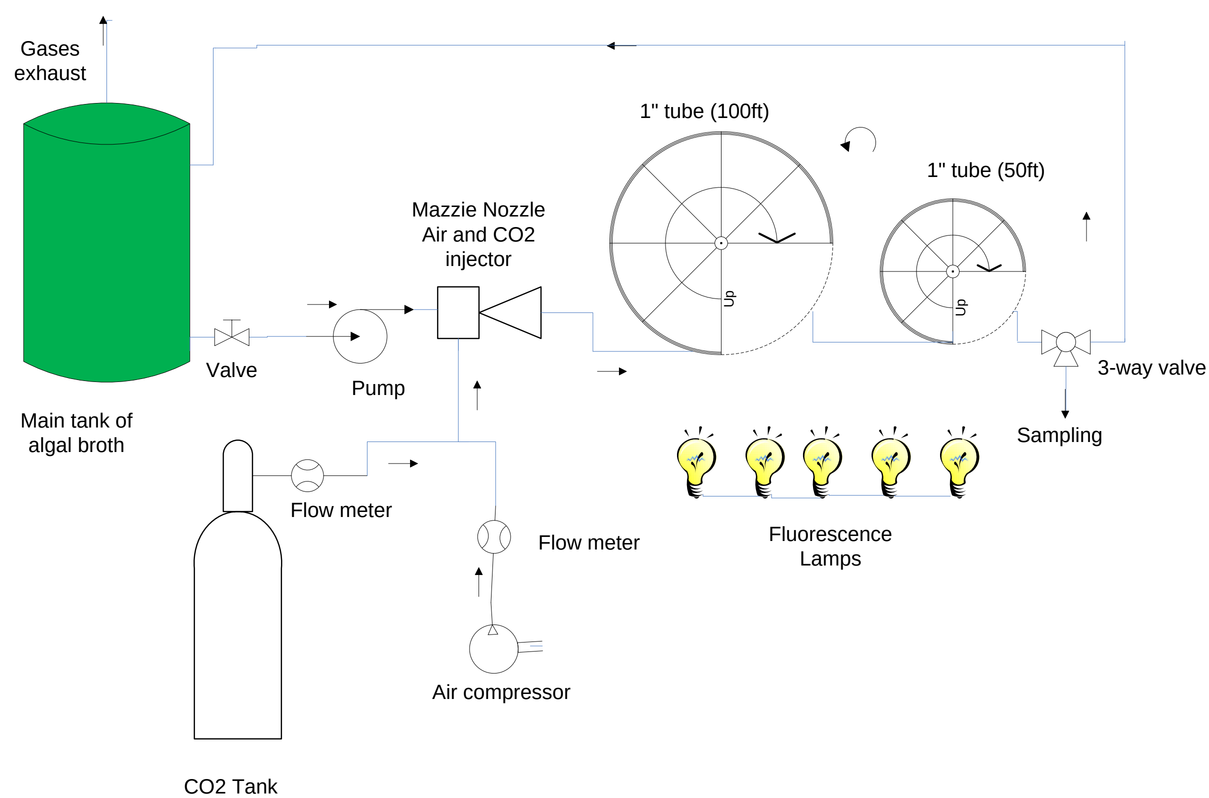
4.2 Photo- bioreactor design

The tubular photo-bioreactor (TPBR) shown in figure 2 was designed and mounted for algal biomass production. It consisted of clear PVC tubing mounted in two spiral, main tank containing algal solution, fluorescence lamps as source of light, carbon dioxide and air sources, and pump which keeps the algal broth in motion in order to avoid microalgae biomass sticking on tubing hall.

Carbon dioxide, nutrients with water placed in main tank and source of photons are needed to grow microalgae. In this design, fluid culture (algal broth in figure 2), which is composed of nutrients and water, is transferred into the tubing using a pump. The pump keeps the fluid culture in motion during the full cycle till the end of the batch when the culture reaches a stationary phase.

An inocolum of microalgal strain is transferred to the batch in a ration of 1:10 (inoculums:medium by volume) in order to minimize the lag phase. Thus the exponential phase is reached within three days and lasts about 10 days. The yield in microalgae biomass in this TPBR is four times higher than yield of microalgae biomass in a cylindrical batch reactor or an open pond. Besides, this TPBR is a closed system, it lessens risks of contamination.

Figure 2: Tubular photo-bioreactor

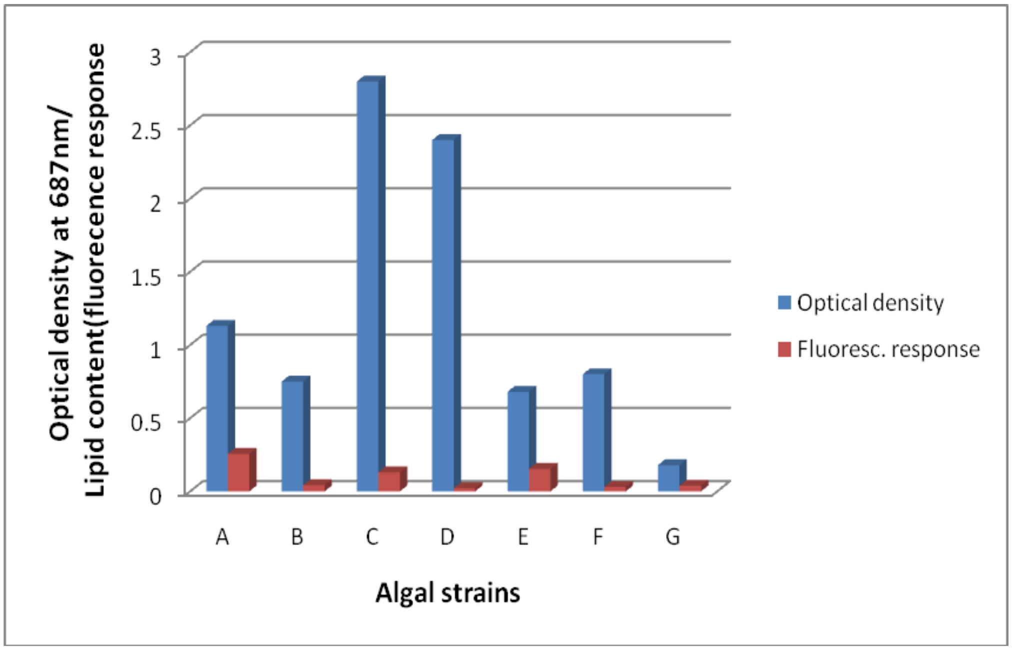


5. RESULTS

5.1 Algae selection

A best algae strain was selected among a seven of screened algae. Strain A resists to contamination from bacteria, viruses and unknown microorganisms that destroy algal cell. It has a high growth rate, which enhance reaching high yield lipid due to high microalgae biomass yield per unit volume of the broth. This strain has been selected for the rest of the study. Figure 3 shows turbidity and lipid content of the seven strains samples.

Figure 3: Turbidity and Lipid Content of Algae strains

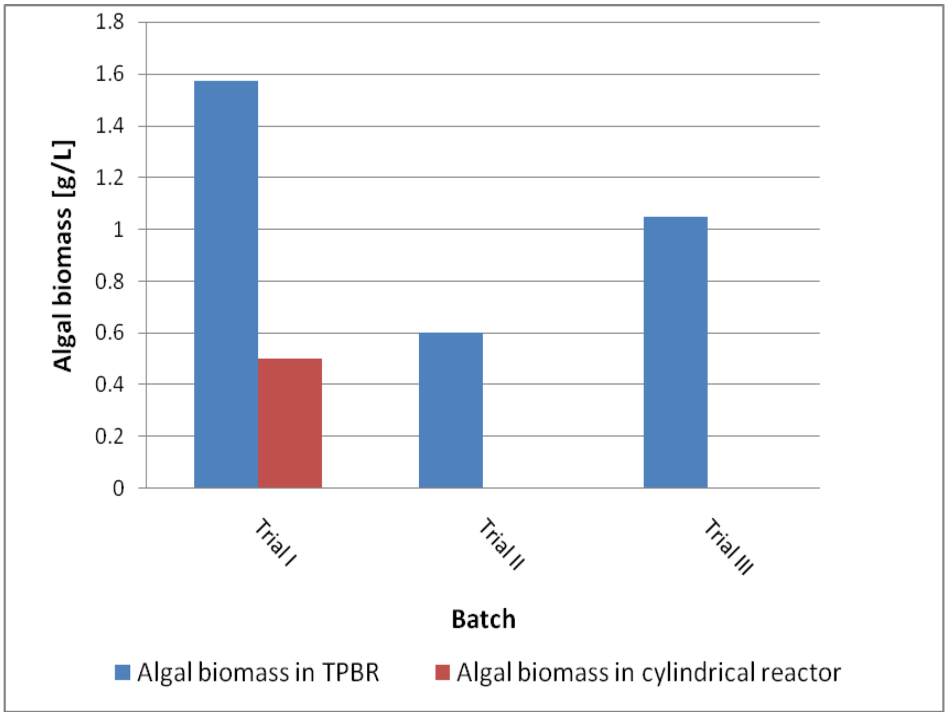


Strain C and D yielded high algal concentration (optical density) shown in figure 3 with low lipid content. On the other hand, strain A yield high lipid content with a good algal concentration.

5.2 Tubular Photo-Bioreactor

The TPBR allows approximately a yield of 1 g of dry microalgae biomass per liter of broth with a culture holding in less than two week using an inoculum transferred at 1:10 ratio (0.1g microalgae biomass per liter of algal broth. Figure 4 shows results of three batches with an average algal biomass of 1g/L. These microalgae biomass yield contain 12.8% algal crude oil (0.128g of crude oil per 1g of dry algal biomass). There is 50% improvement in yield using the above TPBR compare to the cylindrical photo-bioreactor with a culture of the same strain A done in the same conditions in our facilities.

Figure 4: Concentration of mature culture (dry algal biomass per unit volume of algal broth) after two weeks



6. CONCLUSION

A suitable algal strain has been selected for high growth rate and contamination resistance. A Tubular Photo-Bioreactor designed, constructed and operated for 2 weeks yielded high microalgae biomass with high lipid content. The Tubular Photo-Bioreactor demonstrated a possibility of producing significant amount of microalgae biomass at high scale, this has the advantage of generating biodiesel that could compete with petroleum based fuel in quantity.

Microalgae harvested and lipid extraction for biodiesel production as well as in situ transesterification will be performed in the near future and the results will be presented in the August at the 8th World Conference of Chemical Engineers

7. FUTURE WORK

Oil will be extracted from algae, and then converted to biodiesel through transesterification, two-step process. An integrated algae oil extraction and transesterification (in-situ) process will be explored and compared to two-step process.

8. REFERENCE

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