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Exploration of lipid extracted residue of algae biomass as a potential feedstock for biogas generation: Sustainable approach towards integrated bio-refinery

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ABSTRACT

Algae biomass has been recognized as a potential and promising feedstock for biodiesel production. However, the expenses associated with the overall downstream processing steps question the sustainability of algae biodiesel. With an aim to improve this, a sustainable approach has been explored using lipid extracted algae biomass (LEB) of Spirulina platensisas the feedstock for biogas generation. The alternate use of LEB for biogas generation showed the maximum biogas generation of 400 cm3/g of total solids for the total period of 70 days. The volume of biogas generated under the similar experimental conditions using original algae biomass as feedstock was in the similar range as observed with LEB. Theoptimistic results obtained from the study suggested that LEB can definitely be exploited for such applications to improve the overall cost economics of algae bio-refinery.

Keywords : Algae, adsorbent, biogas, dye, wastewater

I. INTRODUCTION

The world is presently confronting the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. Developing countries are in critical energy crisis. The present energy scenario has stimulated active research interest in non-petroleum, renewable, and non-polluting fuels [1, 2]. Alternative resources to the fossil fuels have been sought to mitigate these issues, and various renewable resources have been or are being explored which include solar, wind, geothermal and biomass resources. Among these renewable, biomass energy derived from algae is the potential candidate which can be processed for energy and fuels [3, 4].Algae are the photosynthetic organisms which derive solar energy and carbon dioxide from the atmosphere to form their biomass [5]. They range from unicellular to multicellular, microscopic to gigantic kelps and spherical to filamentous. Algae are considered as good candidate for production of biodiesel due to several reasons like high photosynthetic effectiveness, rapid growth, and high biomass productivity [6, 7, 8, 9]. Algae grow faster than fastest growing terrestrial plant, switch grass. The yield of algae biomass per acre is 200 times above as compared to the yield of the finest performing terrestrial plant [10]. Some algae species can even complete their growing cycle in few days [11].A lot of work can be found in literature dealing with the utilization of various waste materials, such as seed/fruit shells, crop straws, agricultural wastes, fruit peels, etc. for various uses. The production of biogas from various waste materials has also been investigated in many studies reported in literature. Very little information on similar applications of residual algae biomass left after biodiesel production have been reported. A huge amount of residual biomass is left after oil extraction and transesterification. The efficient and eco-friendly utilization of this biomass is essential to overcome the problem of solid waste disposal, which as a result also enhances the sustainability of biodiesel produced.

II. MATERIALS AND METHODS

A. Materials

The algae biomass of *Spirulina platensis* (ASP) in dried and powdered form was procured from the local supplier. The gas samples collected from the digester were analyzed using gas chromatograph (Agilent Technologies 7890 A Agilent GC system) equipped with thermal conductivity detector and Porapak Q column at 250°C and 25°C respectively. The pH of the digestor contents was determined using a pH meter (Systronics 802) and was maintained using diluted hydrochloric acid or sodium hydroxide.

B. Methods

- Pretreatment of lipid extracted algae biomass (LEB)

For the study, the LEB which is lipid extracted algae biomass of *Spirulina* obtained after in-situ transesterification of algae biomass for biodiesel production, was utilized as a precursor feedstock for the generation of raw biogas. The biomass of LEB was collected, washed with water with an aim to remove any unwanted chemicals which was followed by the sun drying. The LEB was then treated in a hot air oven for further drying, grounded and finally sieved (50–100 BSS mesh). The final product was now used as feedstock for biogas generation.

- Experimental set-up

The experimental setup consisted of three plastic containers (Fig. 1) 7 litres each, as batch digesters to carry out anaerobic digestion of the substrate for biogas generation. The biogas generated was collected and measured via water displacement method. The LEB collected used as a substrate for biogas generation. The original algae biomass (ASP) of *Spirulina,* was also used as a substrate to compare the findings with those obtained with LEB. The proximate analysis of the substrates was conducted to determine the volatile matter and the total solids present in them. The total working volume of the digester was maintained as 4 litres while the total solid content for the digestion was kept at 10%. The digester was initially fed with the fresh cow dung for starting up the digester, as cow dung has inherent bacteria which are essential for anaerobic digestion. This time period between the feeding of the digester with cow dung and start of smooth stable operation of the digester was achieved in about 25-30 days. After achieving the stable conditions, as indicated by no further generation of biogas from cow dung present in digester, the substrate slurry along with the inoculum was added to the reactor. The pH of the digester was maintained at 7. The inoculum concentration was kept at 10 % to the total working volume of digester. The substrate slurry was prepared by mixing it with water in the ratio of 3:1(water: substrate on weight basis). The experiments were performed for the total period of 70 days and the temperature of the digester was maintained at 35 ± 2°C with the help of heating tape. The gas samples were collected every 3-4 days and analyzed using gas chromatograph (Agilent Technologies 7890 A Agilent GC system) which was equipped with thermal conductivity detector and Porapak Q column at 250 °C and 25 °C respectively.

Volatile solids (%age of TS)	74.41	70.4

Fig. 1. Pictorial view of biogas reactor

III. RESULTS AND DISCUSSION

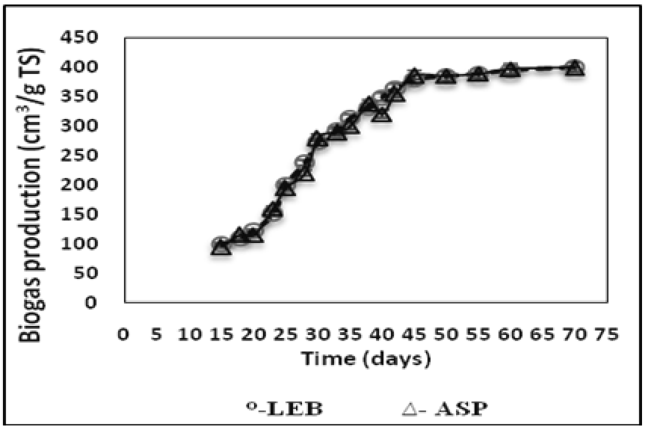
Table 1 shows the composition of air-dried biomass samples of ASP and LEB. The percentage of volatile solids present in both the biomass were found to be in considerable amounts making them quite useful as the substrates for biogas generation. Figure 2 shows the comparison of variation of biogas generation with time (days) using ASP and LEB as substrates. It can be observed in both the cases that initially biogas production was slower but after 15 days the generation became significant which continued until 45 days and then reached equilibrium. After the period of 45 days, the biogas production became stagnant due to the decrease in available nutrients in the medium which could have disturbed the growth of bacteria, thereby affecting the biogas production Figure 2. also shows that the volume of biogas generated under the similar experimental conditions using ASP as feedstock was in the similar range as observed with LEB. The maximum production of biogas obtained was 400 cm^3/g of total solids for the total period of 70 days using LEB as a substrate.

Table 1. Composition of air-dried feedstock for biogas generation

Parameters (%)	ASP	LEB
Moisture	5.2	7.42
Total solids (TS)	94.8	92.58
Volatile solids (%age of TS)	74.41	70.4

IV. CONCLUSION

The alternate use of LEB for biogas generation showed the maximum biogas generation of 400 cm^3/g of total solids for the total period of 70 days. The volume of biogas generated under the similar experimental conditions using original algae biomass as feedstock was in the similar range as observed with LEB. Henceforth, summarizing the entire results of the study conducted it can be concluded that algae biomass left after lipid extraction for biodiesel reduction has the immense potential to be the alternate feedstock for biogas generation. It can concluded from the study that the factors questioning the sustainability of algae biodiesel can be reversed by focusing the research on utilizing the remaining carbon and hydrogen in the biomass for energy generation and secondly by extracting the value added products from the remaining biomass, thus reducing the overall downstream processing costs of biodiesel production and strengthening its economic viability.



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