



III SIMPÓSIO INTERNACIONAL SOBRE GERENCIAMENTO DE
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BIOGAS PRODUCTION FROM MICROALGAE BIOMASS

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ABSTRACT: Oil or ethanol-derived microalgae biomass have been extensively studied as a potential source of biofuel feedstock to meet the world's ambitious goals of replacing our dependence on fossil fuels without simultaneously threaten food supplies. Whereas production of biodiesel and ethanol fuels from microalgae is already occurring in many countries the technologies are not yet broadly available and/ or can be prohibitively costly to implement. To overcome the abovementioned limitations we evaluated the potential of microalgae biomass to produce biogas methane as alternative source of renewable biofuel. Indigenous microalgae *Chlorella vulgaris* was grown autotrophically in a photobioreactor mimicking swine wastewater treatment. The suitability of fresh microalgae as a substrate for biogas production was evaluated using VDI 4630 fermentation assays. Biogas production by microalgae fermentation ($364 \text{ mL}_N \text{ gVS}^{-1}$) was significant compared to standard positive controls ($785 \text{ mL}_N \text{ gVS}^{-1}$). Biogas was composed by 62.6% v/v methane. Major biogas productivity was observed in the first 24 h with $163.24 \text{ mL}_N \text{ g VS}^{-1}$. Overall, these preliminary results indicates that the exceeding microalgae biomass produced during the simultaneous bioremediation of swine waste effluents holds great potential to retrofit anaerobic biodigestors thus enhancing biogas productivity.

Keywords: biogas, methane, microalgae, wastewater treatment

INTRODUCTION

Due to increased demand for agricultural products, intensive systems of swine production concentrates a large number of animals in small areas thus decreasing production costs. However, the environmental sector has not received much attention, especially in relation to the proper management of waste arising from production process, resulting in water (eutrophication) and soil pollution as well as greenhouse gases emissions. The use of phycoremediation (use of microalgae to remove mainly nitrogen and phosphorus from wastewaters) for the treatment of swine wastewater has received significant attention. As a renewable feedstock, microalgae have several benefits, such as high rates of productivity, CO_2 bio-fixation (main carbon source for growth), lowest water demand for its cultivation compared with terrestrial plants, they do not compete with food production in the biofuel production, they can be cultivated in different environments, the nutrients required for growth may be obtained from wastewaters, they present high oil content (20-25% dry matter), they can be used as source of food or as fertilizers and its biochemical composition can be modulated by different growth conditions (Chisti, 2007; Schenk et al., 2008; Borges, 2010; Phukan et al., 2011; Lakaniemi et al., 2011). Microalgae biomass can be further converted into biofuel through different routes, for example, transesterification of lipids to biodiesel, fermentation to bio-ethanol and bio-hydrogen and conversion at high temperatures to produce bio-crude oil (Craggs et al., 2011). The integration of process which combines cultivation microalgae and wastewater treatment systems, aiming CH_4 production appears as



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the most appropriate approach in order to reduce costs associated with production, making it more profitable (Harum et al., 2010). Anaerobic digestion process consists in the biochemical degradation of complex organic matter (Neves, 2009) resulting in the biogas production, which has as main constituent methane (CH₄) and carbon dioxide (CO₂), and trace amounts of hydrogen (H₂), nitrogen (N₂) and hydrogen sulfide (H₂S). The significant amount of biodegradable components (carbohydrates, lipids and proteins) present in the microalgae biomass, makes it a favorable substrate for the anaerobic microbial flora that can be converted into biogas rich in CH₄ (Schenk et al., 2008; Lakaniemi et al., 2011; Prajapati et al., 2012).

In this context, the present study aimed to evaluate the potential usefulness of microalgae biomass produced during the phycoremediation of swine wastewater as an external carbon supply to enhance anaerobic fermentation and biogas generation.

MATERIAL AND METHODS

Indigenous microalgae *Chlorella vulgaris* collected from a local facultative lagoon was grown autotrophically in 15 L cylindrical glass photobioreactors. The photobioreactor was fed with non-sterile effluent from an upflow anaerobic sludge blanket (UASB) biodigester. Effluent characteristics are as follows (g L⁻¹): pH 7.9, 3–8 TSS, 1.5–6.5 TOC, 2.5–4.5 BOD₅, 5–8 CaCO₃ alkalinity, 1.5–2 TN, 0.9–1.5 NH₃-N. Microalgae inoculum consisted of a 30% v/v (10 g L⁻¹ dry weight). Reactor was constantly aerated using a regular aquarium air pump and kept at room temperature (21±1°C). Microalgae biomass was harvested by centrifugation (5 min, 3,500 rpm) and the pellet used as a substrate for fermentative biogas assays.

Substrate fermentation tests were conducted in triplicate with 250 mL glass reactors at 37±2 °C according to VDI 4630 Handbook of Verein Deutscher Ingenieure (VDI 2006). Glass reactors were loaded with an inoculum mixture of 1/3 of biodigested swine wastewater, 1/3 of cattle manure and 1/3 of granular sludge originating from an UASB of a gelatin factory. This inoculum was kept under anaerobic conditions at 36°C at constant stirring (60 rpm) and fed continuously over a period of 5 days with swine food (75% m/m), dried and milled grass (15% m/m), milk powder (5% m/m) and vegetable oil (5% v/v) at a ratio of 0.3 g L⁻¹. Inoculum feeding was ceased 10 days prior to assays. Fermenters consisted of a negative control (inoculum only), positive control (inoculum + microcrystalline cellulose - Sigmacell®, Sigma®, USA), and inoculum + microalgae biomass. Volatile solids (APHA, 2005) content from the microalgae substrate and inoculum were 111.7 ± 0.2 g kg⁻¹ and 36.9 ± 0.4 g kg⁻¹, respectively.

The amount of biogas produced was measured after 24 h with eudiometer test tubes (DIN 1985; VDI, 2006) and the corresponding cumulative volume was calculated as mL g⁻¹ VS. The biogas produced was normalized by the amount of biogas generated by the negative control. Biogas was collected in appropriate bags (Alu-Verbundfolie A 30, Herman Nawrot Ag, Germany) to determination of CO₂ and CH₄ concentrations in a photoacoustic infrared spectroscopy (INOVA 1122, Lumasensetm Technologies inc., USA).

RESULTS AND DISCUSSION

The suitability of fresh microalgae *Chlorella vulgaris* biomass collected from a photobioreactor simulating swine wastewater treatment was evaluated for its potential to produce biogas. There are a number of approaches that considers the compositional data from microalgae species to estimate methane yield. In this work, a total cumulative biogas volume of 364 mL_N g VS⁻¹ (Figure 1) was observed and it is in good agreement with the aforementioned expectations (Sialve et al. 2009, Mussnug et al. 2010, Heaven et al. 2011). Significant biogas production was attained within the first 24 h with the mean value



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equivalent to $163.2 \text{ mL}_N \text{ g VS}^{-1}$. This increased biogas production in the first hours of experiment was most likely due to low levels of complex sugars and lignin present in the microalgae composition that facilitates biodegradability (Vergara-Fernandez et al., 2008, Prajapati et al., 2012). Qualitative analysis of the biogas revealed that it was composed of 62.6% v/v methane, thus corroborating previous studies performed using different microalgae species (Vergara-Fernandes et al. 2008; Mussnug et al. 2010). Interestingly, the amount of methane generated by the fermentation of microalgae biomass ($227,8 \text{ mL}_N \text{ CH}_4 \text{ gVS}^{-1}$) was higher than fattening swine manure [$207.8 \text{ mL}_N \text{ CH}_4 \text{ gVS}^{-1}$; VDI 4630 (2006)]. Cumulative biogas attained by positive control was $785 \text{ mL}_N \text{ g VS}^{-1}$ corroborating to VDI 4630 standards ($740\text{-}750 \text{ mL}_N \text{ gVS}^{-1}$) for 80% of the assays. Despite the fact microalgae fermentation produced only 46.4% v/v biogas compared to standard positive controls, methane content was 4.3% v/v greater (data not shown).

CONCLUSIONS

Preliminary results from this work suggest that it is plausible to utilize the exceeding microalgae biomass generated downstream of swine wastewater treatment processes as additional source of carbon to promote biogas production. To our knowledge, this is the first report on the use of microalgae biomass developed in lab scale photobioreactors treating swine wastewater to serve as methanogenic substrate. Thus, whereas conversion of microalgae feedstock into biodiesel and bioethanol has already been proven, the associated technologies may not yet be widely accessible or prohibitively costly. The implications of this work were twofold: a) first and foremost be in agreement with the current nationwide interest to stimulate biogas production particularly at the agribusiness scenario in order to minimize greenhouse emissions whilst serving as an attractive source of renewable energy, and b) utilize the already existing biogas infrastructure which makes the overall process of using valuable microalgae-derived swine wastewater treatment processes a less complex and costly system to operate.

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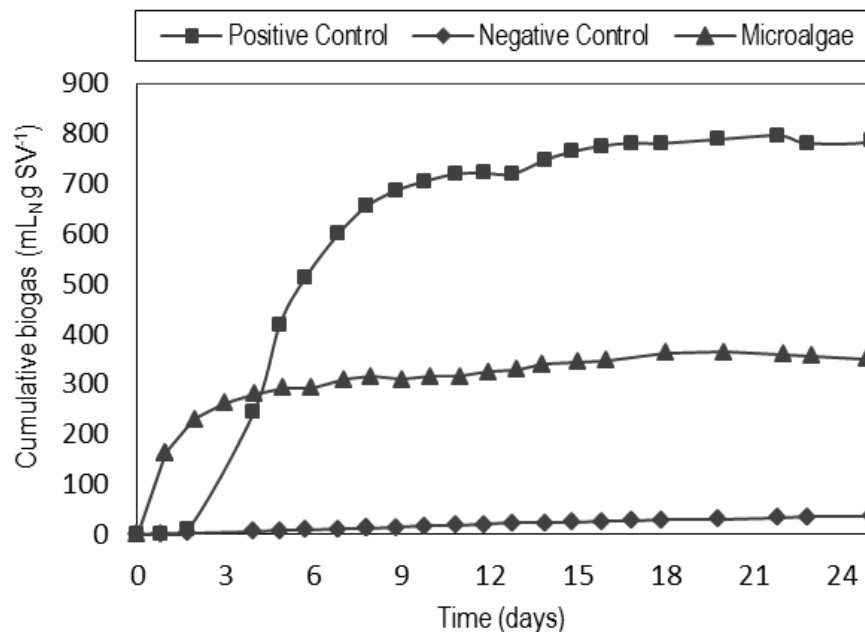


Figure 1 – Cumulative microalgae-derived biogas volume produced over time in fermentative batch reactor assays.