EVALUATION OF THE METHANOGENIC PHASE OF A TWO-PHASE
ANAEROBIC DIGESTION OF P. STRATIOTES BIOMASS

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EVALUATION OF THE METHANOGENIC PHASE OF A TWO-PHASE ANAEROBIC DIGESTION OF P. STRATIOTES BIOMASS

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Abstract

Methane production by aquatic plants’ biomass is a promising option that could help to reduce greenhouse gas emissions and to dispose correctly plant biomass residues. In order to improve the anaerobic degradation of the biomass, the phase separation and the use of inoculants specialized have been tested, both with favorable results. The aim of this study was to evaluate the specific methanogenic activity (SMA) and the methane yield (YP/S) of the effluent from the hydrolysis - acidogenesis of P. stratiotes inoculated with anaerobic sludge. Using a central composite experimental design, the effect of substrate/inoculum ratio (S/I) and the initial pH value were evaluated. With the better S/I and pH initial, the SMA was 0.23 gCOD VS⁻¹ d⁻¹ and methane yield (YP/S) was 22.7 mL VS⁻¹ degraded d⁻¹. The methane conversion efficiency and COD removal (ηCOD) were 44.81%, 82.6% respectively. Therefore, it was concluded that the effluent from the hydrolysis - acidogenesis of P. stratiotes is an excellent methanogenic substrate.

KEYWORDS

Lignocellulosic biomass, Two-phase anaerobic degradation, Bioenergy, Biorefinery, Aquatic plants

INTRODUCTION

The anaerobic digestion of lignocellulosic-rich substrates offers, in a simultaneous way, the capacity to obtain energy in the form of methane and the possibility to dispose the solid waste as soil amender (Yue et al., 2013). However, the low buffer capacity and the fast hydrolysis of the easily-biodegradable portion of some substrates, causes a remarkable acidification (Braun, 2007) which inhibits the methanogenic activity (Cysneiros et al. 2012). The separation of the phases and the use of specialized inocula enhances the stability and performance of the system (De La Rubia et al. 2009, Schievano et al. 2014) in the digestion and co-digestion of lignocellulosic substrates (Kivaisi and Mtila 1997, Lehtomäki and Björnsson 2006, Schievano et al. 2014). The use of lignocellulosic biomass coupled wastewaters and microalgae, as feedstock for the production of bio-energetics and other added-value products has been pursued within an integral system of biorefinery (Olguín, 2012). Previous work has included the evaluation of the hydrolysis-acidogenesis of P. stratiotes inoculated with cow ruminal fluid, obtaining an effluent with a concentration of volatile fatty acids (VFA) of 1,817 mgCOD L⁻¹ (Unpublished data). However, there are not reports of studies concerning the use of this type of effluent for the production
of biogas in two-phase systems, and the optimal relation substrate/inoculum is unknown, as well as the initial value of pH in order to avoid the inhibition of the specific methanogenic activity and the methane yield.

Several authors have used the response surface methodology to evaluate the combined effect of the factors that rule the biotechnological processes such as the hydrolysis-acidogenesis of aquatic plants (Hu et al. 2006, Yue et al. 2007) and the Hydrogen production (Wang and Wan 2009), concluding that this is an adequate methodology for the study of not only every involved factor, but also its interaction, and to be able to determinate the suitable conditions for the best performance of the process.

The aim of this work was to evaluate the specific methanogenic activity (SMA) and the daily methane production yield coefficient (Y<sub>P/S</sub>) of the effluent from the hydrolysis-acidogenesis of <i>P. stratiotes</i> inoculated with anaerobic sludge, and to define the optimal region in which to operate the methanogenesis of this substrate.

**MATERIALS AND METHODS**

The substrate for the methanogenesis phase was obtained from a first hydrolysis–methanogenesis phase of <i>P. stratiotes</i> biomass (15 g<sub>VS</sub> L<sup>-1</sup>, inoculated with ruminal fluid at 20% V/V, at 27 °C and no pH-adjustment), was used as the methanogenic phase substrate. The methanogenic inoculum (I) was obtained from an anaerobic filter, fed with pig manure, with an hydraulic retention time of 25 d and organic load rate of 1.5 kg<sub>VS</sub> m<sup>-3</sup> d<sup>-1</sup>. The effect of substrate/inoculum relation (S/I) and pH<sub>initial</sub>, on both the SMA and Y<sub>P/S</sub> was evaluated by response surface methodology (Montgomery, 2004). With the better S/I and pH<sub>initial</sub> obtained, the methanogenesis kinetics was studied in a batch-operated reactor, according to the results of response surface experiment. The methane conversion efficiency was calculated by the formula given by Koyama <i>et al.</i> (2014). Standard analytical methods were used to all determinations. The gas composition was quantified with gas chromatography with a thermal conductivity detector and a packed column HayeSep 80/100, using Nitrogen as carrier gas at 45 psi pressure and flow rate of 20 mL min<sup>-1</sup>. The injector temperature, oven temperature, and detector temperature were 225, 45, and 250° C, respectively.

**RESULTS AND DISCUSSION**

Evaluation of the S/I and pH<sub>initial</sub> effect in specific methanogenic activity and methane yield

This experiment allowed to evaluate the combined effect of the factors and to define the conditions for the better SMA and Y<sub>P/S</sub>. In the interval tested the S/I and the interaction between S/I and the pH<sub>initial</sub> were the factors that ruled the process. The results showed that both, a high S/I and the SMA and Y<sub>P/S</sub> decreased as the pH<sub>initial</sub> increase, on the other hand, with a lower value of S/I, the variation of pH<sub>initial</sub> had insignificant effect in methanogenesis. The maximum SMA (0.229 g<sub>COD</sub> g<sub>VS</sub> I<sup>-1</sup> d<sup>-1</sup>) and Y<sub>P/S</sub> (26.3 mL<sub>STP</sub> g<sub>VS</sub> degraded d<sup>-1</sup>) were obtained with pH<sub>initial</sub> value of 7.0 and the S/I 2.5 g<sub>COD</sub> g<sub>VS</sub> I<sup>-1</sup> (Figure 1 A and B). Under these operation conditions, the SMA was close to that of the inoculum with acetic acid as a substrate (0.299 g<sub>COD</sub> g<sub>VS</sub> I<sup>-1</sup> d<sup>-1</sup>), which confirms that the substrate does not inhibit methanogenesis.
Evaluation of methanogenesis with the better relation S/I and pH\textsubscript{initial}  
These results showed that at the tenth day the methane production was close to the theoretical production, the COD decreased 74±1.1 % and the VFA consumption was 81.7±5 %, Meanwhile, at the fourteenth day the COD reduction and VFA consumption increased 8 and 16.8%, respectively, suggesting that in two-phase anaerobic digestion of \textit{P. stratiotes}, a period of ten operating days is suitable for the methanogenesis phase (Figure 2).

The daily methane yield was 27.2 mL g\textsubscript{VS\_degraded}^{-1} per \textit{P. stratiotes} biomass gram fed into the hydrolysis - acidogenesis phase. This indicates that it is possible to obtain, with a minimum of operational controls, a methane yield greater than that reported by other authors with another substrates such as \textit{Eichhornia crassipes} (Kivaisi and Mtila 1997) and \textit{Phragmites australis} (Jagadabhi \textit{et al.} 2011), but less than that obtained with grass (Lehtomäki and Björnsson 2006).
CONCLUSIONS
The effluent of the hydrolysis - acidogenesis of *P. stratiotes* biomass was an adequate substrate for the production of methane because it does not inhibit the methanogenic activity. Both SMA and $Y_{P/S}$ were affected by the relation substrate/inoculum and the interaction between S/I and the initial pH. The results showed that the anaerobic degradation of the biomass of *P. stratiotes* in a two-phase system, with minimum operation control, represent a promising option for the final disposal of the biomass and the production of methane. Under the best operation conditions tested, the methane production obtained was 11.8 mL per biomass gram. However, it is necessary to evaluate the performance of the system at a greater scale and in a continuous mode.

REFERENCES


