Production and characterization of biogas obtained from biomass of aquatic plants

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Abstract. The present work describes an experimental investigation concerning the production and characterization of biogas, obtained from biomass of *Eichhornia crassipes* and biomass of aquatic plants mixture (*Eichhornia crassipes*; *Eichhornia azurea*; *Pistia stratiotes* and *Salvinia*). The biogas was obtained in anaerobic biodigestion process. The biogas obtained has considerable tenors of methane, in way to make possible its use.

Key words

Aquatic plants, biogas, biodigestion, renewable energy

1. Introduction

In the hydrological basin of Paraíba do Sul river in Rio de Janeiro State, Brazil, where about 2.4 million inhabitants live, the disordered evolution of urban and industrial development in the area promote a great increase of the pollutant load in the river. This increase of the wastes, mainly the one of organic origin on the rivers, it has been promoting the uncontrolled increase of several aquatic organisms.

Among the several species, the *Eichhornia crassipes* is a peculiar aquatic macrophyte, because it proliferates inordinately in polluted areas. Due to uncommon reproduction process, flotation islands of *Eichhornia crassipes* form great vegetable masses in the water impeding the river traffic, besides hindering the reception of water for treatment stations and turbines of hydroelectric power stations. For minimizing these damages, the governments and the companies are trying to control its proliferation for several means, by making use of mechanical, chemical and biological methods. The great amount of *Eichhornia crassipes* residues in the water becomes an environmental problem. Other aquatic plants, such as: *Eichhornia azurea*; *Pistia stratiotes* and *Salvinia* are also presented in the reservoirs.

The anaerobic biodigestion of these materials is an option to producing biogas and an excellent fertilizer.

1.1. Eichhornia crassipes

Cosmopolitan, widely pantropical distribution [1].

When proliferating in surplus in a hydric resource the *Eichhornia crassipes* it can propitiate the proliferation of insects, reducing the brightness, as well as reducing the tax of oxygen dissolved in the hydric resource, causing ecological unbalance and altering strongly the communities of invertebrate and vertebrates animals [2]. The growth in surplus of the *Eichhornia crassipes* can be chemically or biologically controlled.

The chemical control, in spite of impeding efficiently the growth and development of the biomass of the plant, has as negative factor of altering the quality of the water, causing intoxications or even the death of the aquatic beings. Moreover, it presents a high cost, depending on the area where is applied.

Being so, several attempts and studies have been made with biological controls with can also bring serious problems, altering the ecological balance of the area.

The mechanical control consists of removing the biomass using a manual process and using machines. In both cases, great amounts of residues are generated, many of which are deposited in the soil without any control and special cares, could cause the contamination of the soil, and, still, make the proliferation of insects possible. Therefore, an appropriate destination of this biomass is essential.

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1.2. Eichhornia azurea

Cosmopolitan, widely pantropical distribution [1]. It can be found in the following states of Brazil: Acre, Amapá, Amazonas, Ceará, Goiás, Maranhão, Mato Grosso, Minas Gerais, Pará, Rio de Janeiro, Rio Grande do Sul, Rondônia, Santa Catarina, São Paulo. In South America, besides Brazil, it can be found in Argentina, Uruguay and Paraguay. In Central America it can be found in Nicarágua, México, French Guiana and Guyana. In North America it is widespread in some parts of United States. Also, there are reports of its presence in western India [2].

1.3. Pistia stratiotes

It is disseminated through the tropical regions of the world. It is possible to see its penetration in temperate areas [3]. It also can be found in Europe, Asia and Brazil [4]. In Ceylon, Ghana, Indonesia e Thailand it is considered a pest.

1.4. Salvinia

It is shown as a floating complex of herbs, difficult to be distinguished amongst them. They are native of South America, specifically at Southeastern of Brazil. In the latter half of the twentieth century, they were widely spread throughout the tropics and subtropics areas, due to the trade of ornamental plants for fish breeding ponds and lakes. They form a dense cover on lakes and in slow rivers, causing economic losses and environmental problems for native species and biological communities.

These plants are widely distributed in warm regions of the world such as Africa, India, Southeast Asia and Australia.

1.5. Anaerobic Biodigestion

The anaerobic process is based on the use of microorganisms in the complete absence of free oxygen, for the degradation of the organic matter.

The main microorganisms used in the anaerobic process are the anaerobic bacteria. The capacity of an anaerobic bacterium to decompose a certain substratum is specific, depending mainly on the enzymes that it possesses.

The global efficiency of conversion of the organic matter in stabilized products depends on the efficiency of each reaction and of the balance among several species and among the groups of present bacteria in the anaerobic system. The speed of each reaction influences on the speed of the process.

The biogas obtained in the biodigestion process it is basically a mixture of methane (CH_4) with carbon dioxide (CO_2) and small amounts of hydrosulphuric gas (H_2S), nitrogen (N_2), hydrogen (H_2), oxygen (O_2) and carbon monoxide (CO). The most abundant component in the mixture is the methane wich contributes with 50% to 70%.

There are two basic systems, the continuous and the batch mode. The first appropriate for most of the biomasses receives loads daily or periodically and it unloads the mass fermented automatically by communicating vases in the middle of the operation. The second is specific for organic materials of slow decomposition and of long production period, it receives the total load, keeping it, until finishing the biodigestion process, being then emptied and recharged again.

A review about anaerobic biodigestion is done by Gunaseelan [5].

2. Material and Methods

The aquatic plants (*Eichhornia crassipes, Eichhornia azurea*; *Pistia stratiotes* and *Salvinia*) were collected at Santana and Vigário reservoirs (22^0 28’ 53.15’’ S and 43^0 50’ 17.65’’ W), located at Barra do Piraí City, Rio de Janeiro State, Brazil.

The biodigestor used in the experiment is composed by a reactor, which contains the biomass and where the biogas is produced, and a reservoir for the inspection of the biogas production. The reactor is inside a reservoir containing water. This can be heated up through a thermal resistance, which maintains the temperature inside the reactor around 35^0C.

The adopted procedure contemplates the following stages:

- Triturating totally in industrial liquefier the aquatic plants (root, stem and leaves);
- Filling the reactor with the paste of the plants;
- Filling, with water and salt, the reservoir for inspection of the biogas production;
- Seal the experimental apparatus.

The biogas was analyzed by Gas Chromatography using a CG MASTER equipment with double detector flamme ionization (DIC) and thermal conductivity (DCT).

3. Results and Discussion

It was used an economical bath reactor for evaluating biogas potential of aquatic plants. Wilkie et al. [6] has also used economical bioreactor to study several kinds of biomass.

The Table 1 illustrates the evolution of the experiment of biodigestion of the *Eichhornia crassipes*. It was used in the reactor 2.5 kg of the triturated aquatic plant.

Table 1. Biodigestion of Eichhornia crassipes

DAYS	EXPERIMENT EVOLUTION (% CH_4 gas in the reactor)
1	experiment beginning
14	21.7
21	33.1
28	55.9
35	40.3

The results of the analyses of the gas of the reactor are in Table 2.

Table 2. Biogas composition of Eichhornia crassipes after biodigestion

Biogas composition of Eichhornia crassipes	14 days (vol., %)	21 days (vol., %)	28 days (vol., %)	35 days (vol., %)
O_2	7.1	3.6	2.0	1.2
N_2	22.0	12.4	6.1	5.4
CH_4	21.7	33.1	55.9	40.3
CO_2	48.3	50.8	35.8	52.9
CO	0.15	0.05	0.06	0.08
others	0.75	0.05	0.14	0.12

The tenor of methane in biogas from anaerobic biodigestion of Eichhornia crassipes is about 56%. Others researchers using different types of biomass and different reactors obtained values of 53% to 83% for methane in biogas ([6] to [12]).

The maximum tenor of methane occurred after 28 days of biodigestion of Eichhornia crassipes. The reactor was fed only at the beginning of the experiment. The production of the biogas it was 6 L/kg of wet biomass.

The Table 3 illustrates the evolution of the experiment of biodigestion of aquatic plants mixture (Eichhornia crassipes; Eichhornia azurea; Pistia stratiotes and Salvinia). It was used in the reactor 2.5 kg of the triturated aquatic plant.

Table 3. Biodigestion of aquatic plants mixture (Eichhornia crassipes; Eichhornia azurea; Pistia stratiotes and Salvinia)

DAYS	EXPERIMENT EVOLUTION (% CH_4 gas in the reactor)
1	experiment beginning
7	40.9
14	49.7
21	48.0
28	48.0

The results of the analyses of the gas of the reactor are in Table 4.

Table 4. Biogas composition of aquatic plants mixture (Eichhornia crassipes; Eichhornia azurea; Pistia stratiotes and Salvinia) after biodigestion

Biogas composition of aquatic plants mixture	7 days (vol., %)	14 days (vol., %)	21 days (vol., %)	28 days (vol., %)
O_2	0.9	1.0	1.3	1.2
N_2	2.7	3.1	4.1	3.7
CH_4	40.9	49.7	48.0	48.0
CO_2	55.3	46.1	46.2	46.7
CO	0.05	0.02	0.05	0.02
others	0.15	0.08	0.35	0.38

The tenor of methane in biogas from anaerobic biodigestion of aquatic plants mixture (Eichhornia crassipes; Eichhornia azurea; Pistia stratiotes and Salvinia) is about 50%. Others researchers using different types of biomass and different reactors obtained values of 53% to 83% for methane in biogas ([6] to [12]).

The maximum tenor of methane occurred after 14 days of biodigestion of aquatic plants mixture (Eichhornia crassipes; Eichhornia azurea; Pistia stratiotes and Salvinia). The reactor was fed only at the beginning of the experiment. The production of the biogas it was 5 L/kg of wet biomass.

4. Conclusion

In the process of biodigestion of the aquatic plants it was obtained biogas, with considerable tenors of methane, in way to make possible its use.

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