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Article

Estimation of the Energy Potential by Anaerobic Digestion of Food Waste at Nangui Abrogoua University: Mono-digestion of Food Waste

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ABSTRACT

The food wastes of the Nangui Abrogoua University are rich in organic matter that can promote the production of biogas through anaerobic digestion (AD). These wastes are favorable for the AD process. This study aims at estimating the energy potential of the food wastes of the University Nangui Abrogoua by the production of biogas following the process of AD *batch*. The biogas from this food waste is estimated at 24.45 m^3 or 24,450,000 mL for 30 days. This is equivalent to an energy potential of 171.14 kWh. These results obtained indicate that the food waste of the University Nangui Abrogoua is an important source of renewable energy.

Key words: Anaerobic digestion, Food wastes, Biogas, Energy potential.

1. INTRODUCTION

In Côte d'Ivoire, more than 1.624 million tons of food waste are generated each year, which represents 40–65% of the Municipal Solid Waste [1]. The amount of food waste generated is expected to continue to increase due to population growth and rapid urbanization. In the promotion of sustainable development, universities are important [2]. They are considered "mini cities" with a wide territorial coverage, diverse human activities, which have consequences on the environment [3,4]. Among which we have the restaurants that constitute an important resource of food waste production [5].

The recovery of energy and nutrients from food waste is not only a substantial economic opportunity but also an essential condition for the sustainable development of human society [6-9].

Anaerobic digestion (AD) is the appropriate method for the treatment of such waste and the production of renewable energy [10,11].

The Nangui Abrogoua University has various restaurants and markets, which make it a potential source of food waste. The objective of our study is to estimate the energy potential of the food waste of the University Nangui Abrogoua by anaerobic batch digestion.

2. MATERIALS AND METHODS

2.1. Food Waste and Inoculum

Food waste was collected from the various markets and restaurants within the Nangui Abrogoua University. A mass of 500 g of the food waste sample was pawed using a hand blender type LXH-4413. It consisted of cooked vegetables, fruits, cooked rice, sauces, cooked fish, attiéké, plantain, placali, grilled chicken meat, potato French fries, and yams. The sample was stored in a refrigerator at −4°C until required for the experiments. The waste was, then, thawed at room temperature before experimental use.

The inoculum was collected using sterile polyethylene stomacher bags and transported to the laboratory [12]. The collected cow dung was transferred to a closed container and then acclimated at 37°C in a water bath for 5 days before use.

2.2. Characteristics of Food Waste

Moisture content (%H), Total Solids content (%TS), and Volatile Solids content (%VS) were determined by calculation.

2.2.1. Moisture content

$$\%H = \frac{m_0 - m_1}{m_0}$$

With %H: The moisture content
m_0: The initial mass of the sample before drying
m_1: The mass of the sample after drying.

2.2.2. Total solids content

%TS=100–%H

With %TS: The content of Total Solids.

2.2.3. Volatile solids content

$$\%VS = \frac{m_1 - m_2}{m_1}$$

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With %VS: The Volatile Solids content
m_1: The mass of the sample after drying in the oven
m_2: The mass of the calcined waste.

2.3. AD of Food Waste

The tests were conducted to determine the energy potential of food waste and cow dung. The different masses of food waste used were 10.0 g in digester A; 15.0 g in digester A'; 10.0 g in digester A" and 5.0 g in digester A''' and 10.0 g in digester B; 30.0 g in digester B'; 30.0 g in digester B;" and 20.0 g in digester B''' for cow dung [13]. These tests were performed in 0.8 L of distilled water.

2.4. Stability PARAMETERS

The parameters must be monitored regularly to ensure the proper functioning of the process [14]. In this work, we focused on temperature and pH.

2.4.1. Temperature

The temperature was measured with a thermometer at a time interval of 24 h at room temperature. The temperature was measured from the beginning of the start-up until the AD was stopped.

2.4.2. pH

The pH of each sample of food waste, cow dung, and mixed food waste and cow dung was determined by dissolving them directly in the digesters in a variable substrate mass to distilled water volume ratio [15]. After manual agitation for 3 min, the suspension was allowed to stand for 5 min before taking pH measurements. The reading was taken using a pH meter of the type HANNA HI 8314. This pH meter was calibrated before use with two points of buffer solutions (pH = 4; pH = 7).

2.5. Biogas Yield

Biogas yield during methanation was monitored using the water displacement technique in a gasometer [14,16]. The digester was connected with a transparent, single-layer polyvinyl chloride hose to a gasometer consisting of an inverted graduated flask. When the biogas is produced, it exerts a pressure on the water present in the flask by evacuating it toward the outside of the gasometer.

The biogas yield relative to the total mass of waste (MBR) was determined by the following equation [14]:

$$RBM = \frac{V_B}{m_{substat}}$$

RBM: Biogas yield relative to total substrate mass (mL/g)
V_B: Biogas volume (mL)
$m_{substrat}$: Total mass of substrate (g).

3. RESULTS AND DISCUSSION

3.1. Characteristics of Food Waste

The results of the analysis of the characteristics of food waste and cow dung are presented in Table 1.

Table 1: Characteristics of food waste and cow dung

Parameters	% H	%TS	%VS	VS/TS	% C
Food waste (g)	57.31	42.68	21.85	0.87	38.8
Cow dung (g)	78.23	21.77	76.24	3.5	43.82

The moisture content (%H) of food waste, total solids content (%TS), volatile compound content (%VS), pH, volatile compound/total solids ratio (VS/TS), and carbon content are 57.31; 42.68; 21.85; 5.19; 0.87; and 38.8%, respectively. That of cow dung are 78.23%; 21.77%; 76.24%; 6.39; 3.5; and 43.82, respectively. The high moisture content indicates the high water content of food waste. This value is consistent with that obtained by Kouadio *et al*. [16]. This amount of water in the food waste shows the fermentable character of this waste. AD is therefore appropriate for this type of waste [16,17].

pH is an important parameter for in AD [1,18]. The optimal pH range of food waste for AD is between pH = 6.5 and pH = 8.5 [3,19]. This range is favorable for methanogenic bacteria according to studies by Appels *et al*. [20]. The acidic character of food waste would certainly be due to the presence of organic acids, as waste suspensions have, indeed, a pH that varies between 5 and 9 [21]. The pH of food waste below 6.5 has a negative influence on biogas production, as it affects the activity of bacteria to degrade organic matter into methane as shown by Ali *et al*. [22]. The pH of cow dung being 6.39 ± 0.06 close to neutrality favors the growth of the methanogenic bacterial population. Cow dung waste used as cosubstrate adjusts the pH of food waste [22].

The volatile solids content (%VS) of the food waste is 21.85% due to the high organic load [23]. This value is in harmony with the results obtained by Zhang *et al*. who placed it between 17.1 and 26.35, in the recovery of energetic food waste by AD [24].

3.2. Biogas Volume

Figures 1–4 show the cumulative biogas volume during 30 days of AD of food waste in digesters A, A', A," and A''' and cow dung in digesters B, B', B," and B'''.

The high production of biogas produced during the start of AD would be related to the processes of hydrolysis, acidogenesis, and acetogenesis carried out by the microorganisms [25]. Indeed, this strong increase observed in the volume of biogas at the level of food

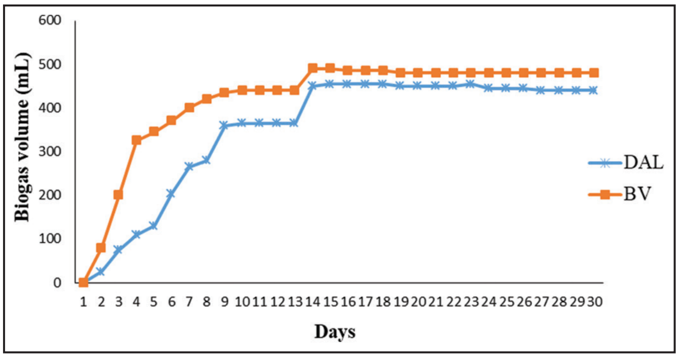

Figure 1: Cumulative biogas volume in trial 1.

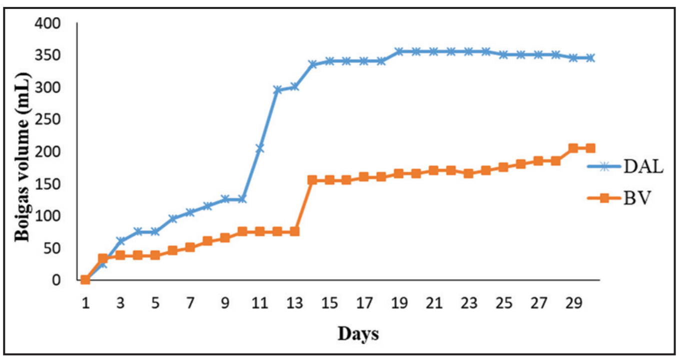

Figure 2: Cumulative biogas volume in trial 2.

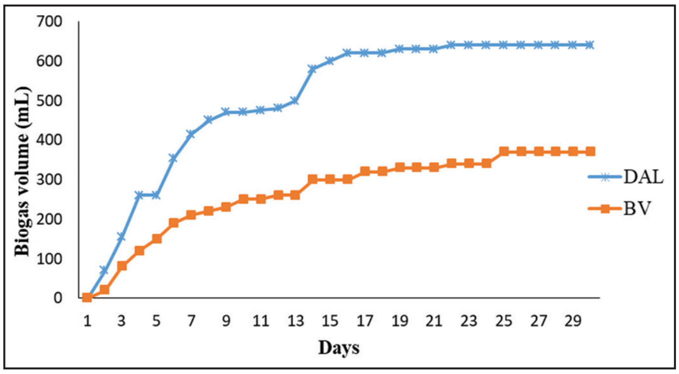

Figure 3: Cumulative biogas volume in trial 3.

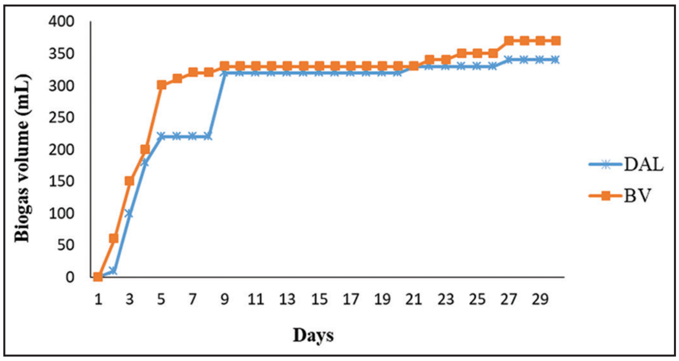

Figure 4: Cumulative biogas volume in trial 4.

waste would be due to an important use of biodegradable organic matter by the microorganisms present in the digester [26,27]. The moderate production of biogas during methanogenesis (stationary phase) would be due to a decrease in the amount of biodegradable organic matter. The sharp drop in biogas production observed, during the decline phase, could be explained by the fact that methanogenic bacteria produce less biogas and more secondary metabolites (VFAs, organic acids) that have an inhibitory action on the methanogenic activity of bacteria due to the progressive lack of organic matter [25,28]. This decrease indicates that the degradation process is nearing its end.

4. CONCLUSION

The study of biogas production from food waste of the University Nangui Abrogoua allowed us to identify and determine the energy potential of this waste through AD. At the end of this study, we conclude that the food waste of the University Nangui Abrogoua constitutes an important source of renewable energy. The food waste has an energy potential of 171.14 kWh for the daily amount of waste produced at this University (24.45 m^3 of biogas) in a 30 day digestion.

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