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Estimation of the Energy Potential by Anaerobic Digestion of Food Waste at Nangui Abrogoua University : Codigestion of Food Waste With Cow Dung

ADJOUMANI RODRIGUE KOUAKOU[1] , ABOLLE ABOLLÉ[1], MARC CYRIL KOUADIO[2], MOYA JOELLE CAROLE AKOSSI[1], EHOUMAN AHISSAN DONATIEN[1], and EDMOND KONAN KOUASSI[1]

[1]Laboratoire de Thermodynamique et de Physico-Chimie du Milieu, UFR Sciences Fondamentales et Appliquées ; Université Nangui Abrogoua ; 02 BP 801 Abidjan 02, Côte d'Ivoire.
[2]Institut de Recherche sur les Energies Nouvelles, Université Nangui Abrogoua, Abidjan, Côte d'Ivoire

Corresponding Author Email:-adjoumanro@gmail.com
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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. These wastes are favorable for the anaerobic digestion 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 anaerobic digestion *batch*. The biogas from this food waste is estimated to be 10.79 m^3 or 10790000 mL over a period of 30 days. This is equivalent to an energy potential of 75.58 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; codigestion

1. Introduction

In Côte d'Ivoire, more than 1.624 million tons of food waste are generated each year, which represents 40 to 65% of the Municipal Solid Waste (MSW)[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[6,7,8,9]. 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. More specifically, we will co-digest the food waste of the University Nangui Abrogoua with the cow dung that constitutes our inoculum.

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), 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

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

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. Experimental setup :

All tests were performed in continuous (in *batch*) digesters for 30 days. These digesters were placed in a device at (37 ± 1) °C (Figure 1). The digester is a 1500 mL vessel with a usable volume of 1000 mL and a headspace of 500 mL. It is equipped with two ports, one for liquid sample

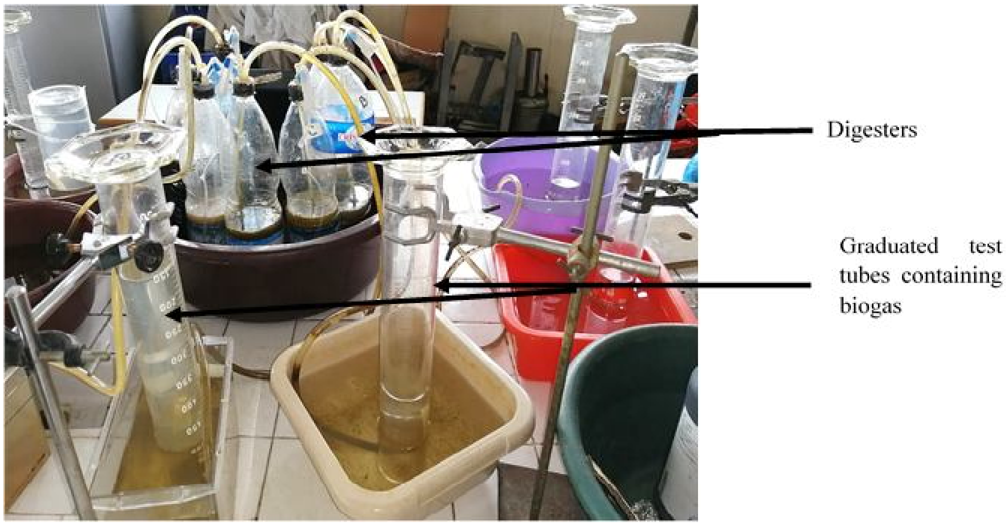

Figure 1 : Experimental setup

collection with a syringe, and the other for recovery and measurement of the volume of biogas produced. The biogas was recovered in inverted graduated test tubes by the water displacement method.

2.4. Codigestion of food waste and cow dung

The different masses of food waste and cow dung used to perform the codigestion tests are shown in (**Table I**). The different ratios (Food waste) / (Cow dung) used are 1/1, 1/2, 1/3 and 1/4 respectively for the mixtures named C, C', C'' and C'''. These tests were performed in 0.8 L of distilled water.

Table I : Proportions of food waste and cow dung used in the codigestion tests in digesters C, C', C'' and C'''.

Digesters		C	C'	C''	C'''
Food waste	Mass of waste (g)	10	15	10	5
Cow dung	Mass of waste (g)	10	30	30	20

2.5. 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.

2.5.1. Temperature

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

2.5.2. 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 minutes, the suspension was allowed to stand for 5 minutes 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).

2.6. 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 (PVC) 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 towards the outside of the gasometer.

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

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

With 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 and inoculum

The results of the analysis of the characteristics of food waste and cow dung are presented in **Table I**

Table I : Characteristics of food waste and cow dung

	% 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; 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. Anaerobic digestion is therefore appropriate for this type of waste[16,17].

pH is an important parameter for in anaerobic digestion[1,18]. The optimal pH range of food waste for anaerobic digestion 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 co-substrate adjusts the pH of the food waste[22].

The volatile solids content (%VS) of food waste which is 21.85% comes from the fact that the organic load is high[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 anaerobic digestion[24].

3.2. Biogas volume

The volume of biogas obtained from the mixture of food waste with cow dung in the digesters C, C', C'' and C''' is represented by **Figure 2**.

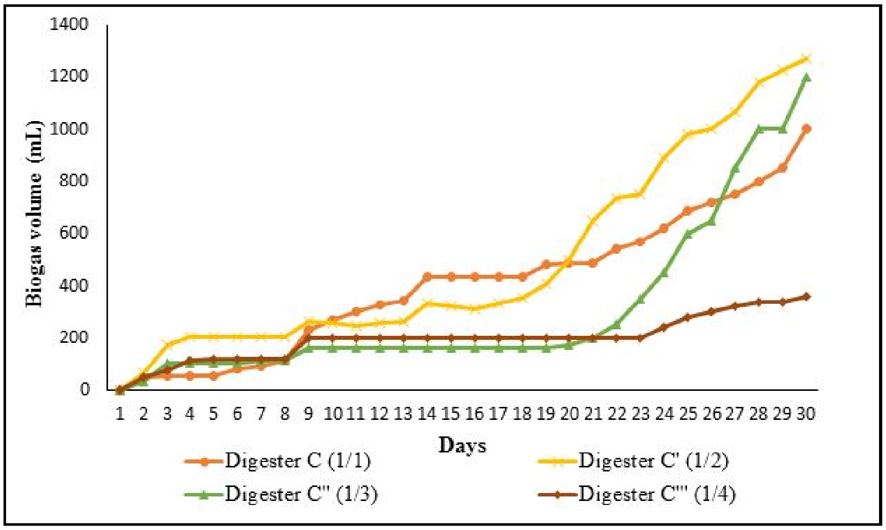

Figure 2 : Cumulative volume of biogas obtained from food waste-cow dung mixtures in digesters C, C', C" and C'''

The cumulative biogas volumes of the mixtures in digesters C, C', C" and C''' during the 30 days of anaerobic digestion are 1000 mL, 1272 mL, 1200 mL and 360 mL respectively. The mixtures of ratios (Food waste) / (Cow dung) corresponding to 1:1, 1:2, 1:3 from digesters C, C' and C" have the high cumulative biogas volumes compared to the mixture from digester C'''.

The higher biogas volumes of the mixtures in digesters C, C' and C" could be attributed to higher biodegradability of these mixtures compared to the others[25].

This higher biodegradability would be related to the high amount of cow dung in these mixtures compared to the organic load contained in the food waste-cow dung mixture. Indeed, a high amount of inoculum adds more anaerobic microorganisms to the digester and thus promotes the biodegradation process[26]. The rate of biodegradation, the lag time and the degradation of the waste, indeed depend on the concentration of microorganisms in the digester[27]. The increase in the cumulative volume of biogas with the decrease in the ratio (food waste) / (cow dung) could also be explained by the increase in the organic load, because the production of biogas is related to the latter[28]. The decrease in biogas volume observed from mixtures with a ratio of (food waste) / (cow dung) = 1/4 would be related to an organic overload leading to an accumulation of volatile fatty acids in the digesters. There is a low biogas production when there is an accumulation of VFA in the digesters. VFA accumulations are frequently observed for high organic loads (ratio (Food waste) / (Cow dung) $\geq$ 1) [29]. The low percentage of accumulated biogas volume from day nine to day twenty-three is thought to be due to a depletion of biodegradable organic matter in the digester or a large accumulation of VFAs [26,29].

Conclusion

At the end of this study, we conclude that food waste from this institution is an important source of renewable energy. The food waste has an energy potential of 75.58 kWh for 10.79 m^3 of biogas during codigestion after 30 days. The codigestion of food waste-cow dung in the proportion 1/2 gives a better amount of biogas which is 1272 mL. The maximum biogas yield relative to the mass in the codigestion is 50 mL/g at the ratio (Food waste) / (Cow dung) = 1/1. The authors would like to thank the LAPISEN of the INPHB of Yamoussoukro for their help in the analyses.

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