Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(10):506-513**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Qualitative Study of Biogas Produced from Cow Dung and Food Residues

***Modou FALL[1], Mamadou WADE[1], Alassane DIENE[1], Gregoire SISSOKO[2]**

[1]Laboratory of sciences and Technology of Water and Environment (LaSTEE), Polytechnic School of Thies, BP A10 Thies, Senegal

[2]Laboratory of Semiconductor and Solar Energy (LASES), department of Physics, Faculty of Sciences and Technology, University Cheikh Anta Diop of Dakar, Senegal

Abstract Organic waste originates mainly from the agro-food industries, cow farmers, field residues, domestic activities, slaughterhouses and urban waste water etc…This waste constitutes an environmental nuisance to be taken into account for the sustainable safeguarding of our environment. Furthermore, recent analytical advancements have led to the detection of a wide variety of organic micro-pollutants [1]. If not properly collected and treated, landfill leachate can contaminate surface water, ground water and soils. To prevent this, collection, treatment and safe disposal of leachate is mandatory [1, 2].

The valorization of this organic matter would be a judicious solution to mitigate their harmful effects. Our work consists in studying the anaerobic digestion of food residues (cooking waste) and cow dung and more particularly the evolution of the volume of biogas produced by the two substrates. In this study, we also followed the evolution of some parameters, namely pH, organic chemical demand (COD), purification efficiency. The results obtained demonstrated the possibility of producing a quantity of flammable biogas for food residues slightly lower than that produced with cow dung for the same hydraulic retention time (HRT) and a purification yield twice as great for than for cow dung.

Keywords Cow dung, food residues, biogas, COD, pH, HRT

Introduction

Methanization or anaerobic digestion is a natural transformation process of organic matter into energy by methanogenic bacteria in the absence of oxygen, conducted in confined spaces called digesters, within which the fermentation reactions are optimized and controlled. These digesters produce biogas mainly composed of methane, while at the same time reducing the organic matter content represented by many biodegradable wastes or by-products [3]. During the anaerobic digestion (AD) process, only part of the organic matter is completely degraded, the rest is an excellent fertilizing agent for agricultural land and can be used as such [4].

The residue of the digestion (or digestate) obtained is stable, deodorized, mostly cleared of the pathogenic germs. Some authors have studied the anaerobic digestion of household waste by comparing the pH adjustment around neutrality (pH 7) [5] and without adjusting the pH to demonstrate its influence on the biogas efficiency. They regularly monitored the pH, the volume of biogas produced, the evolution of Organic Chemical Demand (COD) and Biochemical Oxygen Demand (BOD) as a function of digestion time. In this study, we compared the anaerobic digestion of food residues and cow dung. For this, we followed the COD, the pH evolution and the volume of the biogas produced for the two substrates as a function of the digestion time.

Several parameters are used to control the methanization process, such as pH, COD, dilution ratio, temperature and substrate composition etc.

pH: Care should be taken to keep the pH close to 7. The optimum pH is between 6.5 and 8. If, for an undetermined reason, the pH falls below 6.6, a significant inhibition of methanogenesis occurs.

The temperature: one generally works between 35 - 40 °C. (mesophilic domain). Methane production is possible from 15 °C; It increases rapidly at 20 °C [6, 7],

Hydraulic retention time: The retention time (also the holding time, residence time) is the average time during which a sample remains in the digester [8]. For calculating the hydraulic retention time, all inputs (raw materials and water) to the digester must be considered [9].

$HRT\ (d) = V_{digester} / V_{input}$(1)

$V_{digester}$: Total digestervolume (m^3)

V_{input}: Total daily volume entered in the digester (m^3/d)

Organic loading rate: the organic loading rate is a measure of the amount of organic matter introduced into a digester per unit volume of the digester (normally given in kg. $m^{-3}.j^{-1}$ or kg DCO $m^{-3}.j^{-1}$).

The balance of nutrients is also critical in the AD process. A carbon / nitrogen ratio (*C / N*) of 20 to 30 represents an optimum for biogas production, while excess nitrogen or carbon sources can lead to inhibition [10].

COD: It is defined by NF T-90-101 as the amount of oxygen equivalent to the amount of dichromate consumed by the materials when a sample of water is treated with this oxidant under well-defined conditions [11].

The limiting step of the anaerobic digestion process generally involves four successive phases: hydrolysis and acidogenesis which result in the formation of volatile fatty acids, the acetogenesis responsible for the formation of acetic acid, hydrogen and carbon dioxide and finally methanogenesis which requires precise conditions for its release [11,4].

In this work, we studied the anaerobic digestion of food residues and cow dung. For this, we followed the COD, the pH evolution and the volume of the biogas produced for the two substrates as a function of the digestion time.

Materials and methods

In this study two types of substrates represented respectively by figures 1 and 2 were used to fill the digesters:

- Cow dung, coming from the same group of cows and stored in canvas to avoid loss of water by evaporation or infiltration;
- Food residues consisting of kitchen waste, such as peelings of onions, potatoes, carrots, beets, sausages. These wastes were cut into small pieces to ensure homogenization of the sample.

Figure 1: Cow dung

Figure 2: Residues before and after cutting

They were introduced into 10-liter digesters.

- Cowdung

Figure 3: Digester with cow dung and water mixture

The digester used was fed with a mixture of dung and water in the 1: 1 (v / v) ratio for a total volume of 7.5 liters, operating with a 20-day hydraulic retention time (HRT) and an organic load of 786 074.7 mg for COD. Figure 3 shows the mixture.

- Food residues

The digester is supplied with a mixture of pre-fermented 20 days residues in a hermetically sealed enclosure and water in the proportions 1: 1 (v / v) for a total volume of 7.5 liters, operating with the same hydraulic retention time of 20 days and with an organic load of 1354 mg for COD.

- Determination of organic chemical demand COD

For the Determination of the chemical oxygen demand, we used two methods:

- *1st Method*

We used measuring kits marketed by Hach. These kits consist of tubes containing the reagents in the desired amounts; they enable the determination of the COD within a fixed range. We used tubes for a range of 0-1500 mg O_2/l and 0-15000 mg O_2/l, as shown in figure 4.

It is necessary to dilute the samples to remain within this range of values. A volume of 2 ml of the diluted sample is introduced into a tube and after 2 hours of heating at 150 °C. Using a thermo-reactor (figure 5), the COD is determined by measuring the absorption at 620 nm using an Al800 spectrophotometer (figure 6). In our case, the effluent was diluted by a factor of 10.

Figure 4: Measurement Kits

Figure 5: Thermo-reactor Al125

Figure 6: Al800 Spectrophotometer

- *2nd method*

It is carried out under the action of a strong oxidizing agent (potassium dichromate $K_2Cr_2O_7$), in a strong acid medium (H_2SO_4) and under energetic conditions (2 hours of reflux). Most organic materials are oxidized to CO_2 and H_2O.Silver sulphate is used as a catalyst ($AgSO_4$). The presence of chlorides, bromides and iodides causes interference. They consume part of the catalyst and dichromate. The addition of mercury sulphate eliminates this interference.

$Hg^{2+} + 2Cl^- \rightarrow HgCl_2$(2)

$6Cl^- + Cr_2O_7 + 14H^+ \rightarrow 3Cl_2 + 2Cr^{3+} + 7H_2O$(3)

After the reaction completion, residual dichromate is measured by the addition of ferrous ammonium sulphate (SFA). The indicator used is ferroin (blue green / brown red). The quantity of dichromate consumed is, in fact, measured by difference. The initial amount of bichromate is determined by a control. This process makes it possible to take account of the inevitable losses of the oxidant.

The COD expressed in mg/l of oxygen is given by:

$$\text{DCO(mg/L } O_2) = \frac{(a-b)*\text{N SFA}}{\text{m sample}} * 8000 \text{ (4)}$$

- a = descent of burette for the control
- b = burette descent for the sample
- N = normality of ferrous ammonium sulphate.

$$NSFA = \frac{\text{N bic} * \text{Vbic}}{\text{V SFA}} \text{(5)}$$

NB: Ferrous ammonium sulphate should be standardized using dichromate solution every day.

- The gas flow rate is measured with an experimental eudiometer shown in Figure 7,
- pH is measured using a HANNA 9142 pH meter (Figure 8).

Figure 7: Eudiometer

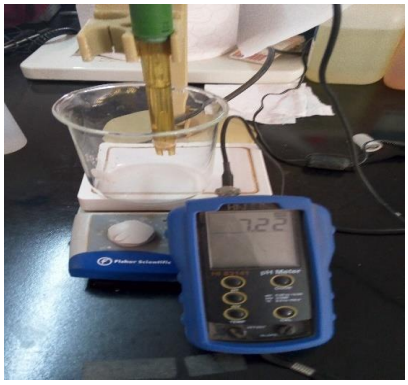

Figure 8: pH meter

Results and Discussion

The measured production represents the maximum amount of biogas that can be produced by a given organic matter. This measure is specific to each product and representative of its level of biodegradability [12].

Evolution of the pH of cow dung digestion

Figure 9 shows the shows the pH evolution of cow dung digestion as a function of time.

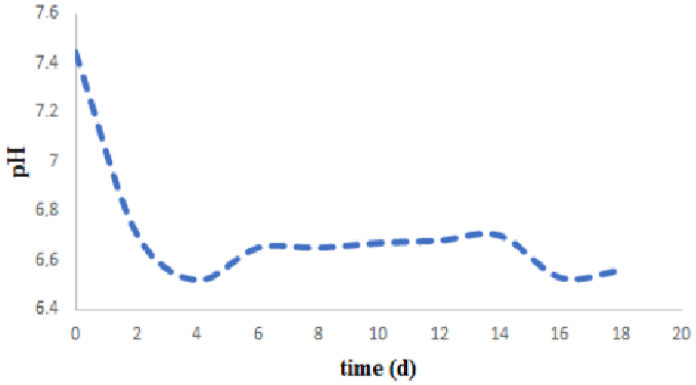

Figure 9: Evolution of the pH as a Function of Time

It shows that pH values range from 7.45 to 6.52 throughout the period of digestion follow-up. In the initial phase of fermentation, a large amount of organic acid is produced by the acidogenic flora, which explains the decrease in pH in the digester. While the digestion process continues, the ammonia (NH_4) concentration increases due to the digestion of nitrogen, which results in a low pH. Cow dung having a low nitrogen content, the variation in pH remains virtually constant.

Evolution of the pH of food residues digestion

Figure 10 shows the pH evolution of food residues digestion as a function of time.

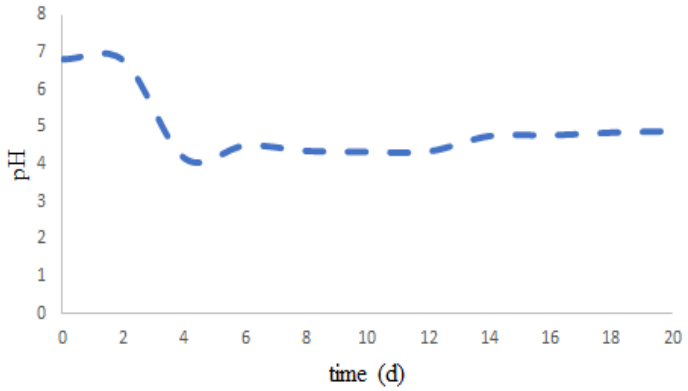

Figure 10: Evolution of the pH as a Function of Time

We find that there is a drop in pH from 6.69 to a minimum value close to 4. This fall is explained by the degradation of organic matter and the formation of organic acids and volatile fatty acids. The drop in pH remained almost stable at around 4.5 more than ten days. A slight increase is recorded from the fourteenth day because the ammonia (NH_4) concentration increases due to the digestion of nitrogen.

Evolution of the volume of biogas for the digestion of cow dung

Figure 11 shows the evolution of the quantity of biogas which is between 0.0008 m^3 and 0.00006 m^3 per day with a maximum production of 0.005086 m^3per day.

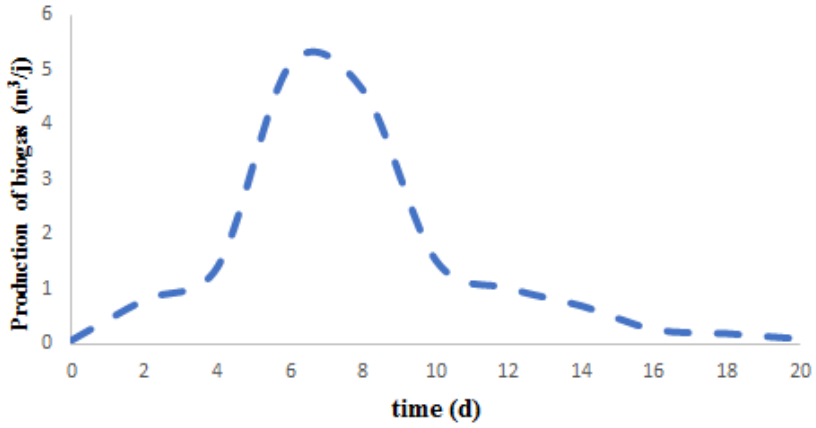

Figure 11: Evolution of the volume of biogas as a function of time

A latent phase of 4 days has been observed since the digester was closed. However, very little production was recorded, estimated at 0.0012 m^3. This period corresponds to the phase of liquefaction during which hydrolysis, acidogenesis and acetogenesis take place. These three steps are responsible for the drop in pH. These stages precede the gasification phase or the methanogenesis which is responsible for the production of the biogas [13,14].

However, this production is limited due to the low digestion temperature and the consequent decrease in pH observed in the first phase of anaerobic digestion, where acetogenesis took place.

Evolution of the volume of biogas for the digestion of food residues

Figure 12 shows the evolution of the amount of biogas produced with food residues which is between 0.000406 m^3 and 0.000107 m^3 per day with a maximum production of 0.003353 m^3 per day.

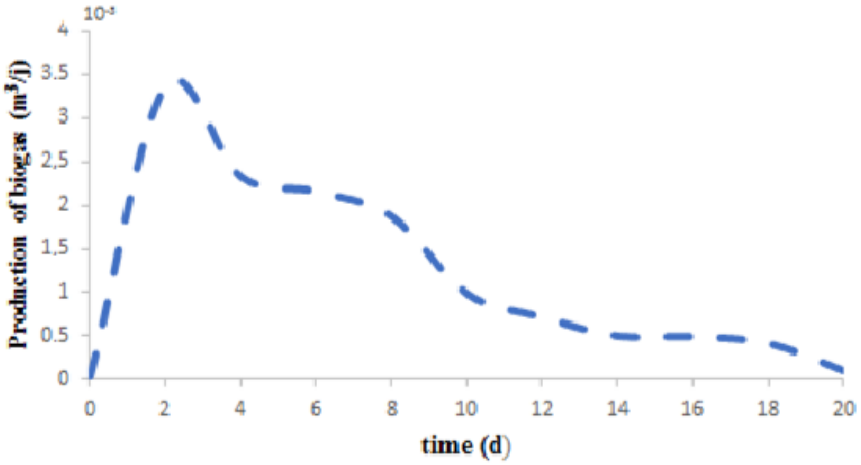

Figure 12: Evolution of the volume of biogas as a function of time

We find that production is limited because of the temperature at which this study took place (27-31 °C) and the drop in pH (up to 4.15) which are not the best conditions for the development of bacteria methanogens. The decrease of the pH to below 4 inevitably implies a significant inhibition of the methanogenesis phase [15].

Comparative study of the evolution of biogas produced from cow dung and food residues

Figure 13 shows the evolution of the different variations in biogas production for the anaerobic digestion of cow dung and food residues.

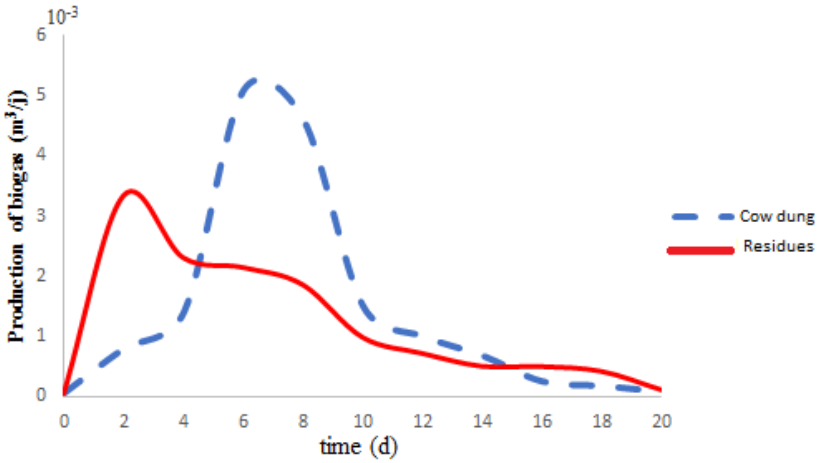

Figure 13: Comparison of the evolution of biogas produced from cow dung and food residues

The production of biogas with residues is slightly lower than that observed with cow dung. A maximum of 5.086 10^{-3} m^3 for cow dung compared with 3.3536 10^{-3} m^3 for food residues is observed, followed by a decrease in cow dung and food residues to the minimum values of 0.06 and 0.107 m^3.

It is also noted that biogas production is earlier with food residues with maximum production from the second day due to the 20-day preferment. Low production of biogas with food residues compared to cow dung reflects the evolution of pH and temperature 27 °C to 31 °C where the experimental study (mesophilic phase) took place.

The purification efficiency

The purification efficiency of the two substrates used is shown in Figure 14.

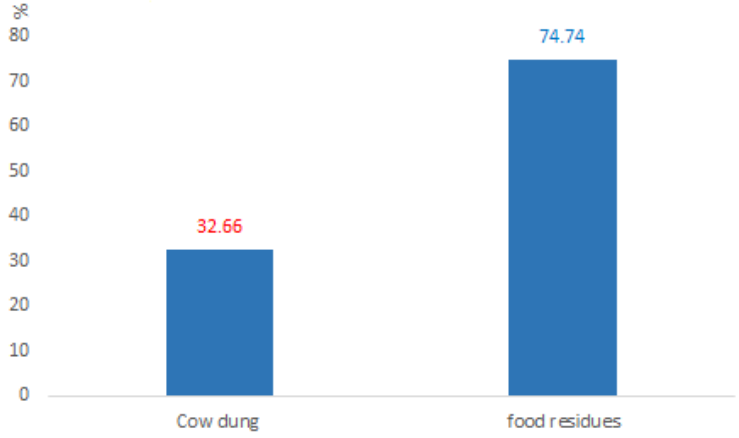

Figure 14: Comparative study of the purification efficiency of cow dung and food residues

The purification efficiency of the two digestion methods is obtained by measuring the COD at the inlet and the outlet. We have a higher purification efficiency for the digestion of food residues (74.74%) than for cow dung (32.66%). These values are in agreement with the results of the pH productivity and the evolution of the biogas production presented above. Indeed, a higher productivity in biogas results in a better degradation of the organic matter (decrease in the quantity of COD) and thus a higher purification efficiency and inversely.

The efficiency would be higher for the adjusted pH than the unadjusted pH. According to S. Kalloum *et al*., the efficiency is 70% for the adjusted pH and 43% for the unadjusted pH for the food residues [16]. The same orders of magnitude have been reported by Yacob *et al* [17] and Parawira [18].

The different results presented during this study show that the characterization of the substrates predicts quite well the performance of the anaerobic digestion of these substrates. This makes it possible in the future to adapt the initial conditions of digestion to the characteristics of the substrates. Furthermore, the evolution of the digestion process can be controlled by monitoring pH and temperature. Thus, it is possible to prevent dysfunction (drop in pH and temperature) by maintaining a constant temperature throughout the digestion process in the mesophilic (37 °C) or thermophilic (57 °C) phases, or directly adjusting the pH by additives such as lime (Na_2CO_3), as reported by S. Kalloum *et al* [3].

Conclusion

The objectives of this study were to experiment and compare the production of biogas by anaerobic digestion of food residues and cow dung. The characterization of the substrates made it possible to calculate the COD and to determine the purification efficiency of the two digestion processes. It is higher for food residues than for cow dung.

From the digestion device carried out, the mesophilic fermentation of the cow dung produced more biogas during the same residence time of 20 days than for the food residues. In terms of productivity, the methanogenic capacity of food residues remains very unexploited compared to cow dung because it requires a longer hydraulic retention time.

References

[1]. Eggen, T., Moeder, M., Arukwe, A., 2010. Municipal landfill leachates: a significant source for new and emerging pollutants. Sci. Total Environ. 2012; 408; 5147–5157.

[2]. E, AhmadiSh. Removal COD of Landfill Leachate Using a Coagulation and Activated Tea Waste (ZnCLR2R) Adsorption. International Journal of Innovative Science, Engineering &Technology, 2017; 4(4):339-347.

[3]. S. Kalloum *et al*, Etude de l'influence du pH sur la production du biogaz à partir des déchets ménagers, Unité de Recherche en Energies Renouvelables en Milieu Saharien, Dec. 2009

[4]. Moleta R.,Techniques de l'Ingénieur**,** Procédés chimie - bio – agro, bio 5100, (2012)

[5]. Kalloum S., Khelafi M., Djaafri M., Tahri A. et Touzi A., Revue des Energies renouvelables, 10 (2007)539-543

[6]. Document, 'L'Incinération des Déchets et la Santé Publique: Bilan des Connaissances Récentes et Evaluation du Risque', ADEME, 1999.

[7]. A. Demuer *et al*., 'Conversion Bioénergétique', Ed. Lavoisier, 311 p., Paris, 1982.

[8]. Document, 'Photosynthèse - Biomasse – Energie – Ressources et Techniques', Collection des Cahiers de l'AFEDES, N°6, Ed. 1982.

[9]. Dr. Amrit B. Karkiet Al**,** Biogaz as Renewable Source of Energy in Nepal Theory and Development, BPS- Nepal, july.2005.

[10]. Wang Z. *et al*., Bioresource Technology, 144 (2013) 281-287.

[11]. Bernhard Drosg**,** Process monitoring in biogas plants, energy technology network IEA Bioenergy, 2013.

[12]. Monique TARDAT-HENRY, Jean-Paul BEAUDRY, Chimie des eaux, Le Griffon d'argile inc, Mai 1985

[13]. Philippe POUECH et Al, Intérêt de la co-digestion pour la valorisation des lisiers et le traitement de déchets fermentescibles à l'échelle d'un territoire. Journées Recherche Porcine, 37, 39-44, 2005

[14]. P.H. Suding, ''La place du biogaz dans le développement des énergies nouvelles et renouvelables en Afrique'', Le développement du biogaz en Afrique. Séminaire, atelier de travail, Bujumbura, 1991.

[15]. I. Tou, S. Igoud, et A. Touzi, ''Production de biométhane à partir des déjections animales'', Revue des Energies Renouvelables, N° spécial : Biomasse, production et valorisation, 2001, 103-108.

[16]. S. Amir, 'Contribution à la Valorisation de Boues de Stations d'Epuration par Compostage: Devenir des Micropolluants Métalliques et Organiques et Bilan Humique du Compost', Thèse de Doctorat, Institut National Polytechnique, Toulouse, France, 2005.

[17]. S. Yacob, Y. Shirai, M.A. Hassan, M. Wakisaka and S. Subash, 'Start-up Operation of Semi-Commercial Closed Anaerobic Digester for Palm Oil Mill Effluent Treatment', Process Biochemistry, Vol. 41, N°4, pp. 962 – 964, 2006.

[18].]W. Parawira, M. Murto, R. Zvauya and B. Mattiasson, 'Comparative Performance of a UASB Reactor and an Anaerobic Packed-Bed Reactor when Treating Potato Waste Leachate', Renewable Energy, Vol. 31, N°6, pp. 893 – 903, 2006.