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Research Article

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Energy Valuation of Animal Excrement in the Production of Biogas: Study of the Biomethanation of Rabbit Dungs in Laboratory in Senegal

DJEUKOUA Benjamin[1*], El hadji Mamadou SONKO[2], NGUEPJOP Joël Romaric[3] and NGANLO KEGUEP Estelle Manuela[4]

[1]*University of Cheikh Anta Diop of Dakar, Institute of Environmental Sciences, B.P. 5005 Dakar-Fann, Senegal*

[2]*University of Cheikh Anta Diop of Dakar Institute of Environmental Sciences, B.P. 5005 Dakar-Fann*

[3]*Regional study Centre for the improvement of Adaptation to drought (CERAAS), BP 3320, Thiès, Sénégal*

[4]*Growth Continue Consulting Dakar Senegal*

***Corresponding author**
DJEUKOUA Benjamin, University of Cheikh Anta Diop of Dakar, Institute of Environmental Sciences, B.P. 5005 Dakar-Fann, Senegal. Tel: +221 776106244, E-mail: ben.djeukoua@gmail.com

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Abstract

Domestic biogas is increasingly seen as an alternative solution to the access to energy in rural areas in Africa. However, incubation will necessarily pass through the use of accessible substrates and high methanogenic power. The aim of this study is to produce biogas based on rabbit dungs in semi-controlled environments. The methodology used is essentially based on the determination of the methanogenic potential of rabbit dungs, dungs co-digested with sludge and market waste and the methane yield. The assessment of the production of the different mixtures in the laboratory shows that it is the combination of dungs and market waste which gives the best methane yield with 85.8%, followed by combinations of dungs and sludge, dungs and sewage sludge which respectively produce 66.5% and 66.2% of methane. Finally, the dungs alone recorded a 50% yield of methane. The biofertilizers obtained from the anaerobic digestion of dungs can be valued as a fertilizer in agriculture and as a nutrient in fish farming.

Thereby, the valorization of rabbit dungs in the production of biogas can open interesting perspectives in energy production and in the fight against climate change (greenhouse gas).

Keywords: renewable energy, biogas; biodigester; methane; rabbits dungs; methanogenic power.

Introduction

In developing countries, wood and charcoal are the most commonly used fuels. Households depend on firewood for: food cooking, heating and lighting homes etc. The energy deficit in rural areas, particularly in terms of cooking energy and domestic lighting, is a constraint on the development of households. Up to 90% of rural households in developing countries use solid biofuels for domestic energy production [1].

Around 87% of households use dead wood for cooking [2]. That is 1.7 million tons of wood per year and 3 hours of time lost daily by women in the search for wood. In addition, cow dung which is the main substrate for biodigesters is subject to competition (for many uses) in rural areas, is only available for a short period of the year and requires half a dozen of cows to ensure the production of the raw material (cow dung).

Unlike cow dung, rabbit droppings offer several benefits such as:

- The permanent availability of the raw material throughout the year;
- The amount of rabbit dung produced is quite high (around 300 hard droppings / day / rabbit);
- The prolificacy of rabbits (40 to 50 rabbits / year / rabbit);
- Rabbit flocks are easier to build because they are economically more accessible.

As such, biogas (which is a mixture of combustible methane and carbon dioxide, produced by anaerobic fermentation of organic matter from animal and plant biomass), as an alternative energy to wood energy and charcoal, fits perfectly with the strategic orientations of the State of Senegal in terms of energy-mix policy. Therefore, it is a shared priority for all development actors and is of national significance because of the existing biomass potential.

In view of these situations, the study of the methanogenic potential of substrates such as rabbit dung as a main substrate or in co-digestion with other substrates (green market waste, sludge and agricultural residues) for the production of biogas and biofertilizer could be an alternative that would help reduce household energy bills, restore and improve soil fertility and increase crop productivity. It can also help reduce greenhouse gases (GHGs), reduce smoke-related respiratory diseases and promote environmentally friendly development. We were interested to discover the real methanogenic potential for the production of biogas from rabbit droppings.

As a result, the general objective of this study is to contribute to the knowledge of the methanogenic potential of rabbit droppings as an alternative to the conventional substrate forms currently underway in Senegal. Specifically, it is a question of evaluating the amount of methane produced during fermentation of rabbit droppings in semi-controlled environments.

Material and Methods

This part describes the materials and methods used.

Materials

The material is two categories: biological and physical material.

Biological material

The biological material is made up here of the rabbit and its dung.

The rabbit

The rabbit is a prolific herbivore that converts vegetable proteins that are not or little used for human food or even other animals into high-value animal proteins with a relatively efficient conversion factor. In addition, because of its prolificacy (40 to 50 young rabbits per year), the energy production of its droppings is interesting, compared to other species [3]. A rabbit can produce about 300 hard droppings a day. This makes it an important material potential for the biodigester.

Droppings of rabbits

The droppings (dungs) of rabbits are about 10 millimeters in diameter [4, 5]. Rabbits throw their dung at random, according to their movements, but also in very particular places. Digestive physiology is dominated by caecotrophy, not to be confused with coprophagia (consumption of faeces); in fact, two types of dung can be distinguished in the rabbit: the caecotrophs, small glossy, soft, clustered clusters most often in clusters and very fragrant, particularly rich in proteins, vitamins and minerals and consumed by the rabbit; and round, hard and dry droppings, on the other hand, constitute waste [6].

Physical materials

For the implementation of the experimental device, the following equipment was used.

- Biogas analyzer, for the analysis of the chemical composition of the biogas produced;
- Laboratory water bath with a capacity of six reactors (biodigesters);
- Electronic scale for measuring different samples (substrates);
- Water tank containing the test pieces;
- burner for the flame test;
- Recipe tubes (Erlenmeyer glasses);
- Mini reactor or biodigesters in which are introduced the different substrates;
- Pipes conveying biogas;
- Flexible hoses with an orifice plug;
- Thermometer for measuring the temperature of the water bath.

Table 1: Composition of hard and caecotrophic droppings

	Hard dung		Caecotrophes	
	Average	*Extremes*	Average	*Extremes*
• Dry matter (%)	**53,3**	*48-66*	**27,1**	*18-37*
in % of the dry matter				
• Proteins	**13,1**	*9-25*	**29,5**	*21-37*
• Crude fiber	**37,8**	*22-54*	**22,0**	*14-33*
• Lipids	**02,6**	*1,3-5,3*	**02,4**	*1,0-4,6*
• Minerals	**08,9**	*3-14*	**10,8**	*6-18*

Source: http://www.cuniculture.info/Docs/Biology/biology-04.htm

The different mixtures (treatments) that were carried out during this experiment are shown in Table 2 below. The first reactor is mainly loaded with (100%) rabbit droppings, the other three reactors are loaded with 50% of rabbit droppings and 50% of one of the co-substrates (sludge, sewage sludge and waste green market).

Table 2: Proportion of rabbit dung and co-substrates mixtures

Rabbit dung and co-substrates mixtures				
Treatments (T)	Rabbit Dung (%)	Fecal sludge (%)	Sewage sludge (%)	Market wastes (%)
T1	100	0	0	0
T2	50	50	0	0
T3	50	0	50	0
T4	50	0	0	50

Operating conditions

We adopted the methane fermentation in “batch” condition. The methane fermentation in “batch” is a discontinuous fermentation where the bioreactor is loaded at the beginning and discharged at the end of the anaerobic process [7].

Fermenters or biodigesters are composed of flasks loaded with substrates are submitted to an incubation time of 37 days. Sealing tests are carried out to avoid the air inlet and outlet that would disturb the process. The digesters are placed in a laboratory water bath. Monitoring of the anaerobic digestion process is performed at a temperature of 37°C.

Description of the experimental device

The experimental device contains five (05) bio digesters or biological reactors (1000 mL flasks) of the “batch” type, each of which is closed by means of a stopper pierced with an orifice through which a flexible hose passes, allowing the transport of the biogas produced over time to collection tubes (1000 ml storage), inverted and suspended in a tank filled with about one third of its volume by water, containing salt (NaCl). The biodigestors are individually connected to a water column in the test tubes, allowing visual measurement of the volume of biogas produced per day. The guard liquid of the test specimen consists of a saturated solution of NaCl, allowing minimizing the dissolution of CO2. The bio digesters are placed in a thermostatic laboratory water bath at 37°C. A regular addition of water is made in the laboratory water bath to fill the losses due to evaporation. Also, the water temperature of the laboratory water bath is monitored with a thermometer to check for temperature differences [8]. The diagram of the experimental device is presented in Figure 1.

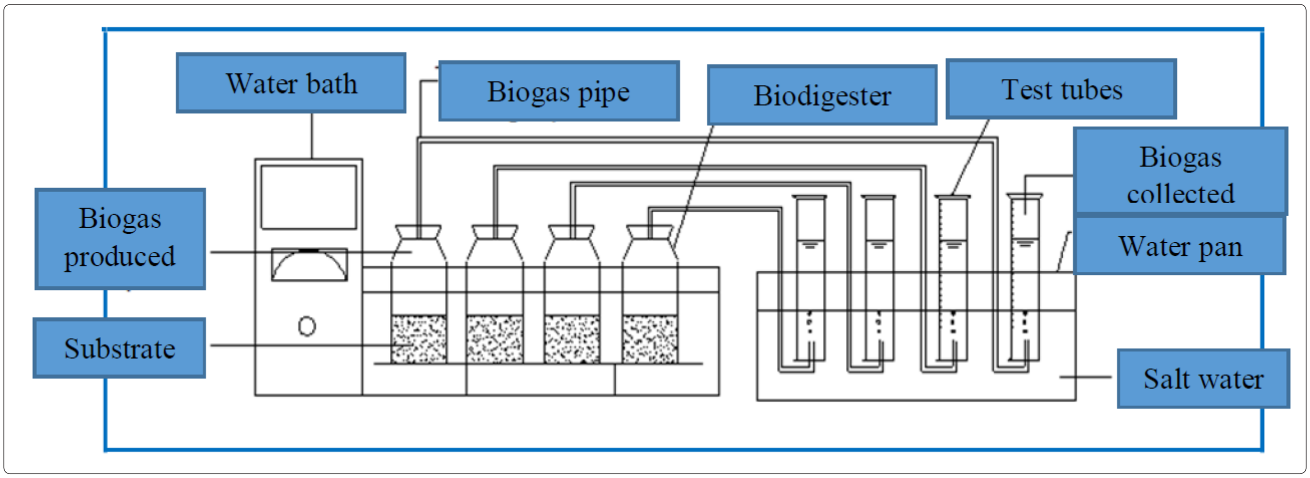

Figure 1: Schematic of the experimental device of the BMP test

Experimental implementation

Bio-Methanation Test or Bmp Test

The bio-methanization potential test, or methanogenic potential test or BMP (Biochemical Methane Potential), makes it possible to determine, under anaerobic conditions, the maximum biogas production of a biomass sample [9]. During this test, the productions of biogas as well as the methane composition are measured.

The principle is to load the fermenters of experimental substrates with a load of 150g and to follow the cumulative production of gas under the pre-established incubation conditions.
Once the substrate is introduced, the temperature of the reactors is raised to 37°C using the water bath thus allowing the conversion of the biodegradable part of the experimental substrates and leading to the production of biogas.

We chose the mesophilic diet (temperature between 35 and 40° C), because of his optimal bacterial activity at this temperature. There was no addition of inoculum because the sludge and dung already contain anaerobic microorganisms. Also, we note that the air retained in the bio digesters is not chased. Indeed, this air will be evacuated by the pressure difference to the test tubes. The bio digestion test is done in a "batch" system for 32 days.

The extraction of the digestates was done on the 32nd day. The BMP value is the amount of gas accumulated after 32 days of incubation.

Production Monitoring and Biogas Analysis

During the methanogenic potential test, the volume of biogas produced daily is measured. A visual reading of the gas production for each biodigester is thus made by means of the graduations of the test piece. The biogas produces, creates an additional pressure and the pressure gradient generates a shift of the gas produced from the reactor to the test tube. The volume of water displaced corresponds to the volume of biogas produced. The movement of the guard liquid allows a measure of the volume of biogas produced (Figure 2).

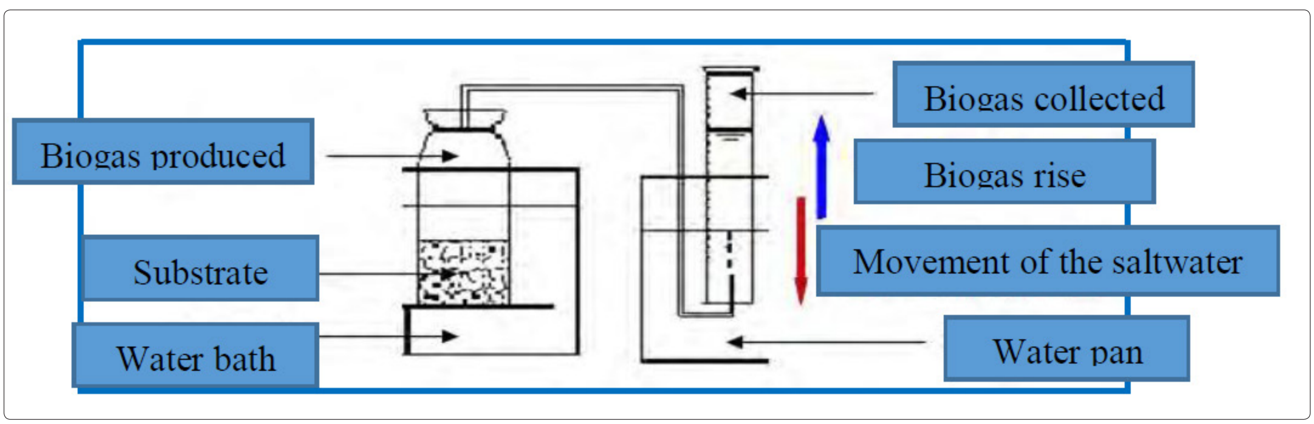

Figure 2: Flow of water and gas in the test tube during fermentation

Thus, when a volume of gas rises in the test tube, the water column moves proportionally downwards from the immersed part of the test tube into the water tank.

The analysis of the biogas composition is done directly using the biogas analyzer. The approach is as follows:

- agitation of biodigesters to allow the rise of biogas;
- reading the level of the gas column;
- purging the biogas analyzer to flush out the residual methane until the zero is displayed on the analyzer screen;
- placing the gas analyzer on the pipe up to the gas column;
- verification of the closing and sealing of the circuit;
- triggering of the analyzer pump and pumping to the vacuum gas column;
- reading of the maximum displayed percentage of methane gas.

The biogas analyzer is connected to an Erlenmeyer flask as a hydraulic primer to prevent entry of water into the biogas analyzer. Thus, the water pumped during the biogas measurement is collected in the Erlenmeyer flask, which will be emptied when it reaches a critical volume.

Results and Discussions

Quantitative evaluation of biogas production

The daily and cumulative biogas productions of the different substrates are shown in Figure 3 below.

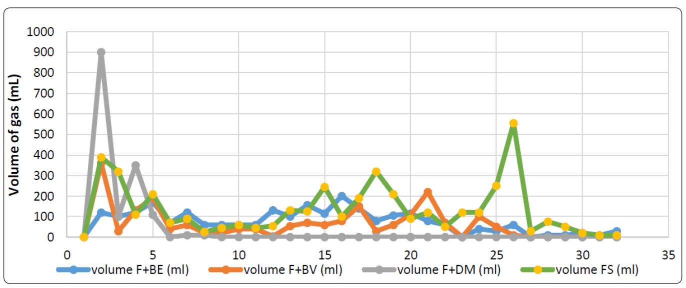

Figure 3: Evolution curve of daily biogas production

The biogas production of the 50% dungs + 50% market green waste (F + DM) mixture reached a peak of 900 mL and represents the highest daily peak on all the different mixtures. This performance is due to the fact that the lag phase (corresponds to a period of metabolic adaptation of the microorganism in the middle) which is normally slow, has been very short. Which accelerated the exponential phase of substrate degradation? However, the high biogas production of this mixture is only observed during the first six (06) days. From the 7th day of fermentation, the production of biogas will tumble from 110 to 10 ml. From the 9th day, the rabbit dung (FS) + market green waste (DM) mixture no longer produces biogas.

Only the dung alone (FS) record a constant production (nearly four high peaks of more than 300 ml) throughout the duration of the experiment. This performance is explained by the progressive activity of bacteria responsible for the degradation of organic matter and corresponds to the acidogenesis phase which is 30 to 40 times faster than the hydrolysis phase [10].

Cumulative Production of Biogas

The cumulative production of biogas during the experiment is shown in Figure 4 below.

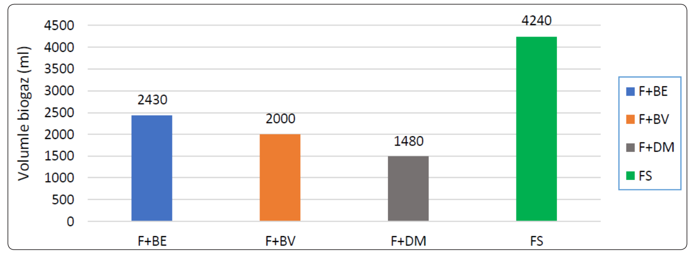

Figure 4: Diagram of cumulative biogas production of the different mixtures

The dung alone (FS) have the best cumulative production with nearly 4240 ml of biogas, followed by the cumulative production of the mixture of rabbit dung (F) + sewage sludge (BE) and rabbit dung (F) + sludge (BV) which represents respectively a volume of 2430 ml and 2000 ml.

While the total production after 32 days of fermentation of the rabbit dung (F) + market green waste (DM) mixture gives a volume of 1480 ml. The lowest biogas production is recorded at the level of the rabbit dung (F) + market green waste (DM). This is the smallest biogas production in terms of volume.

Qualitative Evolution of Biogas Productivity

The quality of the biogas obtained in this experiment is shown in figure 5.

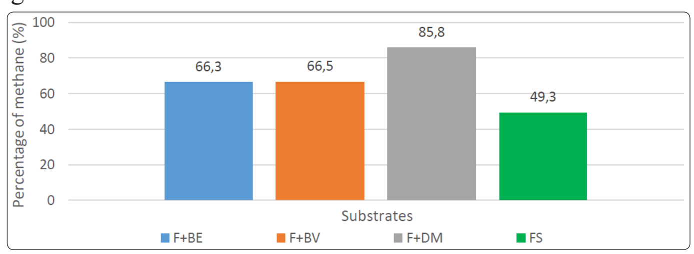

Figure 5: Diagram of cumulative production of biogas and methane composition

The quality of the biogas is essentially evaluated by the percentage of methane (CH_4) it contains. A biogas is even better than its percentage in methane is high [11].

The results of this study allow us to see that the rabbit dung (F) + market green waste (DM) component gave the best performance in terms of methane, around 85.81% of the total production of the mixture. This performance is followed by the rabbit dung (F) + sludge (BV) component with 66.50%, followed by the rabbit dung (F) + sewage sludge (BE) blend with 66.25% and finally the rabbit dung alone (FS) give a yield of nearly 50%.

These results can be explained by the quality of the substrate (dung) and co-substrates (sludge, sewage sludge and green waste market) used. Indeed, the nature of the substrate and the operating conditions during anaerobic digestion determine the chemical composition of the biogas [12]. Indeed, rabbit dungs by their composition do not include lignin, which is a difficult to degrade component. This absence of lignin avoids the pre treatment process and this facilitates their hydrolysis and their methanogens. Improvement of the biodegradability of these lignocellulosic substrates is therefore not considered in the context of the use of cow dung which consists of a large fraction of lignin [8]. The results obtained by the rabbit dung (F) + market green waste (DM) mixture can be explained by the fact that green market waste is also rich in carbohydrates, which are nutritive elements of fermentable bacteria and therefore more easily degradable.

Conclusion

Laboratory experiments on anaerobic digestion of different co-substrates associated with rabbit dungs show that dungs are biomethanizable. Indeed, the results of our experiment show that among the four substrates used, it is the component dung + green waste of market (F + DM) which gave the best yield in terms of production of methane, followed respectively by dung (F) + sludge (BV), dung (F) + sewage sludge (BE) and dung alone. Overall methane production was above average (67.14% of total methane production from all blends). Knowing that the nature of the substrate and the operating conditions during anaerobic digestion determine the chemical composition of biogas, the experiment demonstrated the superior quality of rabbit droppings in the production of biogas. The combination with other substrates has also shown that this has a considerable effect on methane production because the dung alone produce around 50% of the methane during fermentation, associated with sludge and purification, the volume increases by almost 70% and exceeds the 85% mark when it is associated with green market waste [14].

Rabbit dungs are interesting to use because they allow a very good regeneration of bacterial populations favourable to anaerobic digestion. They are produced in large quantities, which make it possible to overcome the problem of the availability of the raw material for biodigesters.

Acknowledgments

In view of the problem of the availability of the raw material for the feeding of the traditional biodigesters implanted in the country for the valorisation of biogas, this research focused on the study of the methanogen potential of the dung of Rabbits as a substitute for cow dung in the co-digestion of biodegradable materials and biogas production. This work was carried out in the research laboratory of the National Sanitation Office in Senegal (ONAS) of Camberene in Dakar. Our sincere thanks to the staff: Mrs. Ms. Dr. R. Nancy, head of the laboratory and Mr. Ousmane DIALLO, who, by welcoming us into their laboratory, allowed us to integrate a research team and thus benefit from experiences for the realization of this work.

Author's Contributions

The experiment was conducted in a controlled environment. The equipment and materials come from the laboratories of the National Sanitation Office of Senegal, under the constant supervision of Laboratory Manager Ms. Aissatou NDOYE and Dr. Alsane SECK. The experiments are carried out with the help of the laboratory team. The data are analyzed by the authors. The authors do not have competing financial interests.

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