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(Research Article)

Effect of recycling digestate filtrate for cow dung dilution on biogas production

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Abstract

Biogas production in the Sahelian zone faces the problem of water shortage. This is one of the biggest obstacles encountered by projects to substitute firewood by biogas in this areas. The study aims to improve the accessibility of households to biogas in water shortage conditions by recycling the filtrate of the digestate into a new dilution of the substrate for biogas production. Thus, the Cow Dung (CD) digestate from the biogas unit was filtered. Filter with sand and cotton and filter with sand, biochar, and cotton were made. The filtrate obtained was used to make five treatments with CD to feed mini biodigesters (1st generation) of 1 liter each. After a HRT of 30 days, the digestate from the 1st generation was again filtered and reused to dilute five treatment (2nd generation). The biogas production and pH of each treatment repeated three times were evaluated. The results show that the dilution of CD with the filtrate from the 1st generation significantly improves the production of biogas by 47% compared to that of dung diluted with ordinary water. In the 2nd generation, dilution with OW provided the highest production which is 7% more than that obtained from the filtrates without biochar. As the pH is concerned, it varies between 6 and 7.5 when filtrates are used. It was more acidic when OW has been used. It appears that, the same quantity of water can be used three times for substrate dilution. This leads to less water demand for biogas unit running.

Keywords: Digestate; Filtrate; Biogas; Substrate; Water; Far North

1. Introduction

Energy is the basis for development. However, in recent years, the world has been facing huge energy problems. Fossil fuels are becoming increasingly scarce, even though they are the most widely used sources [1]. However, wood is the main source of energy in most African countries [2]. It is used for cooking, heating, and crafts [3]. When considering the total amount of wood used as an energy source, Africa consumes 90% of the wood from the forest (natural and planted) [4], [5]. According to the National Institute of Statistics (NIS), 96.3% of the population in rural areas in Cameroon depend mainly on wood energy to prepare meals [6]. This proportion is higher in the Far North Region where environment is closely desertic. The highly dependence on firewood explains the strong pressure of the population on the rare woody plants found in its already naturally fragile ecology. This situation has created a large market for wood energy in urban areas [7]. According to Tunk et al., (2016), the wood energy trade is one of the four main economic activities in the city of Maroua [8]. A study conducted by MINFOF (2014) revealed that demand for this fuel was much higher than supply [9]. It indicated a deficit of 45% in 2022. The threat appears to be increasingly intense, especially in a region that is the poorest and declared by the Cameroonian government as an economically affected area. Initiatives are being taken to

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offer the population an alternative source of cooking energy. The one aiming at the promotion of biogas in rural areas seems to be the most adequate. However, the constraint linked to the availability of water for the proper functioning of the biodigester must be overcome. Indeed, the Far North region, located in the Sahelian zone, has a low water resource. Sometimes water points are very rare and the whole village converges there to get a few liters after waiting several hours [10]. The Mandara Mountains Development Authority (MIDIMA) quoted by Yopo [11] estimated the rate of drinking water supply to be 1 water point for about 1737 people. According to Yopo [11], most wells and boreholes up to 61% are non-functional due to water shortage during the dry season. Women and children can sometimes walk up to 10 km to have access to a water point. Water shortages have their peak in March and April [12], [13]. In this context where access to water is difficult, the normal operation of a biodigester to generate biogas to substitute firewood is almost impossible in some localities. Indeed, anaerobic digestion requires enough water daily to dilute the substrate. The digestate discharged from the system is almost liquid. We, therefore, questioned whether the water in the digestate could be recycled for reuse in the biodigester to continue producing biogas. This concern motivated us to initiate this study on the recycling of the water from digestate for biogas production. The main objective is to evaluate the effect of the digestate filtrate on the anaerobic digestion of the cow dung. Specifically, this is to test the filtration of the digestate, to measure the biogas production and pH of cow dung diluted essentially with the filtrate.

2. Material and methods

2.1. Digestate Filtration Test

For filtration, digestate was collected from a city biogas plant. Two types of sand filters were made with some references to the biosand filter principle [14]. The first one consists of a layer of sand (8 cm), gravel (5 cm), biochar (3 cm), and cotton (0.2 cm thick) [15, 16]. The second one differs from the first only by the absence of the biochar layer. The size of sand particles used is 0.8 mm. For the gravel, it varies between 6 mm and 12 mm [17, 18]. The following figure 1 shows the experimental filtration setup.

(a) (b) (c)

Figure 1 Experimental filter (a) before the filter layers are inserted, (b) filter without a biochar layer, (c) filter with a biochar layer

2.2. The biogas production with recycled water

Table 1 Different treatments used with filtrate

Treatments	Cow dung (CD in Kg)	Ordinary Water (OW in L)	Filtrate without biochar (Fi without Bio in L)	Filtrate with biochar (Fi with Bio in L)
CD+OW (Control)	0.75	0.75	0	0
CD + Fi without Bio	0.75	0	0.75	0
CD+ Fi without Bio + OW	0.75	0.375	0.375	0
CD+ Fi with Bio	0.75	0	0	0.75
CD + Fi with Bio + OW	0.75	0.375	0	0.375

The biogas production was carried out with cow dung. Two generations of the filtrate were tested. The first generation is the filtrate obtained after the first biogas production cycle. The second generation is the filtrate from the digestate of the second production cycle. This is water that has already been used twice in a biodigester. The filtrate obtained from each type of filter was subjected to four treatments and control tests which are repeated three times. The filtrate is used to dilute fresh cow dung at a rate of 1:1 to feed 1.5-liter of mini biodigesters. These different treatments are summarized in Table 1.

2.3. Evaluation of biogas production

The quantity of biogas produced by the different mini-digesters was measured every 2 days during the hydraulic retention time of 30 days. This was done according to th e method used by Tizé et al. (2015). The biogas generated was quantified using polyethylene bags to collect the gas produced by each bioreactor. The bag containing gas was carefully tied and placed in a 1000 mL beaker and held at the bottom by a funnel. The gas from the plastic occupies a certain volume of the beaker. This was topped up to 1000 mL with tap water while ensuring that the gas bag was fully submerged. After removing the gas bag and the funnel, the water level in the beaker drops. The difference in volume corresponds to the volume occupied by the gas, the gas bag and the funnel (V). Thus, an empty bag of the same kind and the funnel are again placed at the bottom of the beaker and occupy a volume. With a known amount of water in a test tube, the volume is adjusted again to 1000 mL. The amount of water used in the latter case constitutes the volume of gas (Vg) contained in the plastic [19].

Production was monitored and regularly quantified throughout the anaerobic digestion cycle. The auto-ignition test of the produced gas was performed at each quantification of the production. The digestion took place in a mesophilic zone, which is favorable for methanization [20] .

2.4. The pH measurement

The pH was measured with a EUTECH INSTRUMENTS pH meter twice a week. The probe is introduced into the beaker containing the solution taken from the mini-bioreactor through a pipe that is arranged in it and the pH value is valid when the pH-meter displays 'READY'. The pH variation curves of the different solutions combined with the histograms illustrating the biogas production kinetics were plotted using Excel software.

2.5. Statistical analysis of data

The collected data were subjected to statistical analysis using Microsoft Office Excel. The analysis consisted of calculating the mean and standard deviation of biogas production. The same software allowed us to draw the curves.

3. Results and discussion

3.1. Filtration of Digestate

For the first generation of mini-bioreactors, we carried out 02 filtrations of 15 liters of digestate, 7.5 liters per filter type. In the second generation, 22.5 L of digestate from the first generation was filtered. The filtration was carried out according to the treatments in the first generation. It has been observed that the filtrate flow rate is 0.17 L/h when using a filter without a biochar layer and 0.2 L/h in the filter with a biochar layer. From this, it appears that the biochar would improve the flow rate in a filtration. The flow rates of our two filters are slow compared to the biosand filter used by Budeli (2021).

Figure 2 Digestate filtrate to be recycled for biogas production

In the 2nd generation, the flow rate was 0.15 L/h in each. On average, 88.88% of the water used to dilute the dung was recovered for the second generation biogas production. And the solid product is a good organic fertilizer [21, 22]. It contains phosphorus (P_2O_5) and potassium (K_2O) [23-24, 25] . Many researchers continued to study the effect of biogas effluent on plant growth [26]. The appearance of the filtrate obtained is shown in figure 2.

3.2. Biogas production

3.2.1. The first generation

After monitoring the evolution of biogas production and pH over one month, we analyzed the data collected. Indeed, the biogas produced is stored in plastic (figure 3 a), then evaluated and tested for flammability. The flammability test of the gas would therefore give a more accurate idea of the nature of the gas, i.e. whether the gas obtained is indeed methane-rich biogas. The positive test produces a blue flame as shown on figure 3b.

(a) (b)

Figure 3 Biogas production; a- quantity produced in polyethylene plastics in 2 days, b-flame color of the biogas produced

The cumulative average production of the five 1st generation treatments was calculated. Figure 4 illustrates the kinetics of biogas production using recycled water from the first digestate as previously indicated.

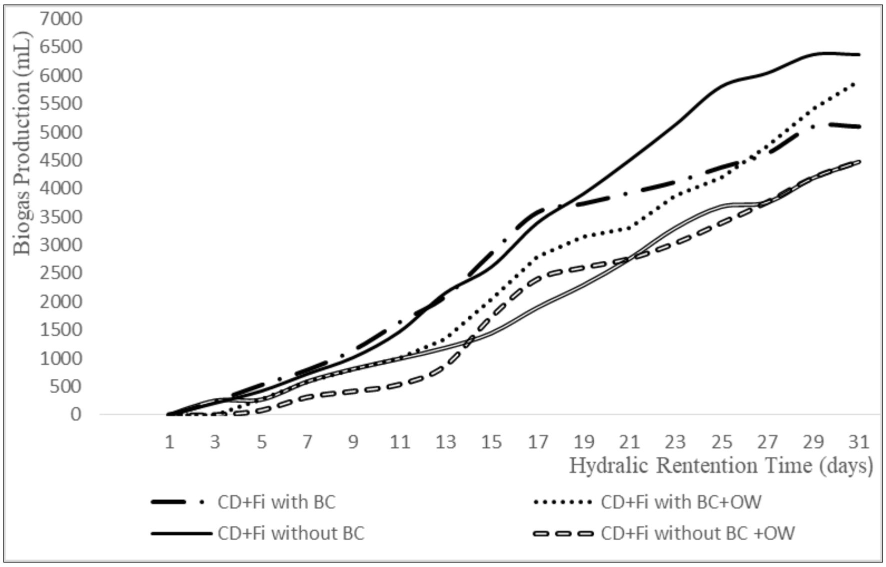

Figure 4 Cumulative production kinetics of the first generation

The figure 4 above shows that the highest cumulative production of the 1st generation is slightly less than 6500 mL. In fact, in this generation of biogas productions, the cow dung treatment diluted with filtrate without biochar (CD + Fi without Bio) recorded the highest biogas volume (6369 mL). It is 7.9% and 47% higher than the productions of the cow dung diluted with ordinary water and filtrate from the filter with a biochar layer (CD + Fi with Bio + OW) and the control respectively. Therefore, it appears that recycling the filtrate to the first generation improves the substrate productivity by almost two times compared to the use of tap water. As for the effects of filtrate with biochar on production, it appears that it favors a better production during the first 16 days of anaerobic digestion. In general, we found that recycling the water contained in the digestate to re-dilute the cow dung for biogas production has a positive influence on the yield. The following figure 5 shows the evolution the average pH as a function of HRT.

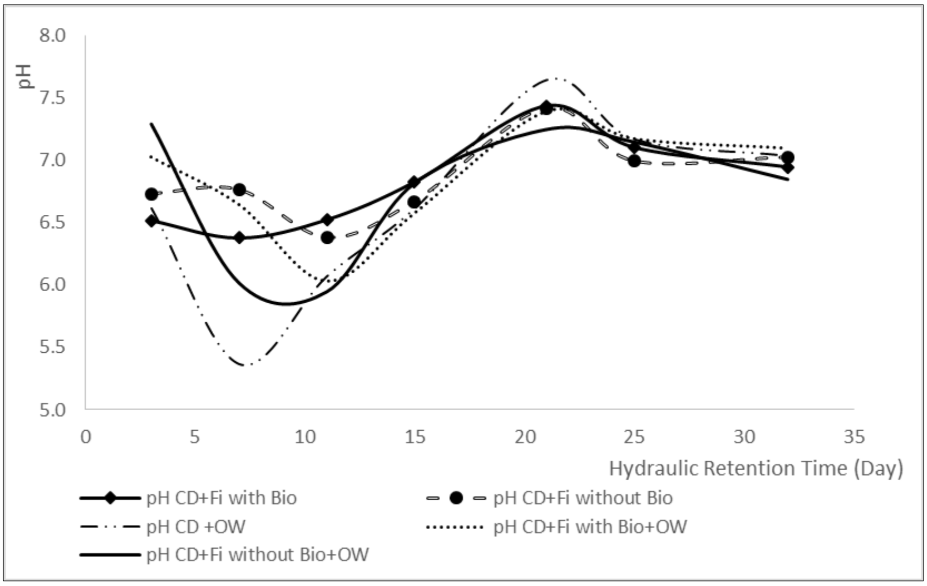

Figure 5 pH fluctuation during the production of the first generation

On figure 5 above, we can see overall that in addition to promoting better production, the filtrates help to maintain the digestion pH around neutrality. It varies between 6.5 and 7.5, which is the best pH range for anaerobic digestion [27],[19]. The acidification phase is almost absent. However, during the first week of anaerobic digestion of cow dung using ordinary water, the pH drop from 7.5 to 5.4 was observed. The similar acidity was also noticed in the mini-biodigesters where dilution was done using ordinary water and filtrate. Dilution of the substrate mainly with ordinary water or in combination with the filtrate caused a drop in pH. However, filtrate helps to arise the pH. This situation could be due to the population of methanogenic bacteria which is probably highly concentrated in filtrate and rapidly converting volatile fatty acids responsible of pH drops during biogas production.

3.2.2. The second generation

The curves on figure 6 are obtained from the average values of biogas production in the 2nd generation.

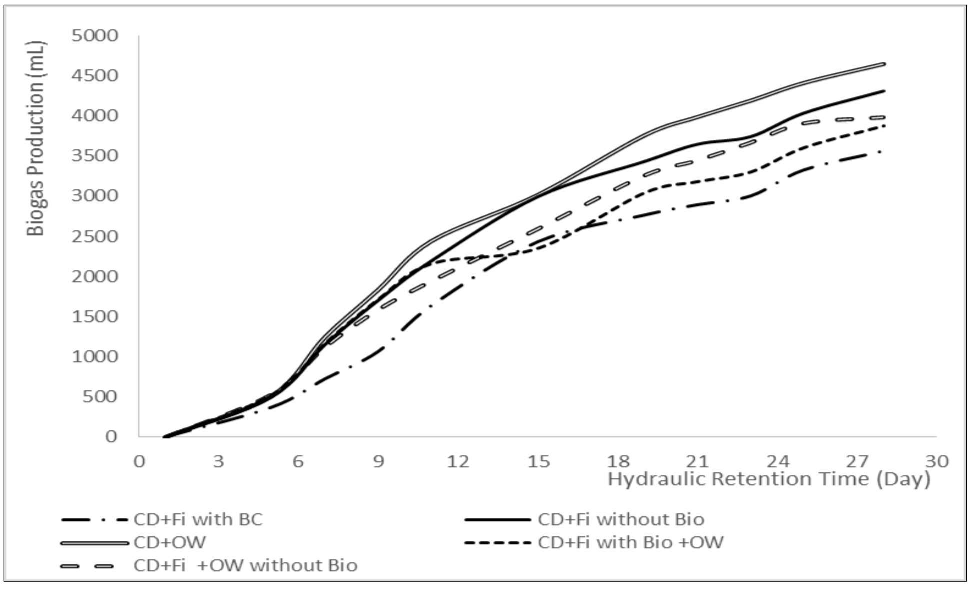

Figure 6 Kinetic of cumulative biogas productions of the 2nd generation

In contrast to the first generation, figure 6 shows that during the second generation, the cow dung treatment diluted with ordinary water was the most productive (4647 mL) throughout the 28 days of HRT. This was followed by the one diluted with filtrate without biochar (4311 mL). However, the difference was 7.7%. The poorest performance was observed in the treatments that were diluted with biochar filtrate. Its production was 30% lower than that of the best treatment (cow dung + ordinary water). This could be explained by the fact that water recycled several times would have become less and less suitable for anaerobic digestion. The accumulation of nutrients in the recycled water would therefore have a negative impact on the productivity of these treatments.

4. Conclusion

At the end of this study, it appears that there is a good possibility to recycle the water contained in the digestate for the reproduction of biogas. With the help of a simple filter made of sand, gravel, cotton, and to certain extent biochar, filtration is effective. In this way, about 89% of the water used in the dilution process can be recovered and recycled. After a one-month follow-up of the first generation of these reused water in the mini digesters, we notice that it improves the biogas production yield (qualitatively and quantitatively) compared to the use of tap water. It is also found that the CD + Fi without Bio in the first generation produces more than the others (6369 mL). However, when the same water is reused for the third time in the biodigester (2nd generation), the production drops. Indeed, in the second generation, the CD + OW treatment was the most productive (4647 mL) but which is just 7.7% more than the production of CD + Fi without Bio. From the above results, a given quantity of water can be reused three times for substrate dilution during biogas production. This could be highly favorable for a proper biogas unit running in the context of water shortage such as the Sahelian zone of the Far North Region of Cameroon.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors of this paper declare that there is no conflict of interest exists.

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