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A Biogas Production Model from Pig Manure: Comparison between Modern and Local Pig Ma-nure in N'zérékoré City, Republic of Guinea

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ABSTRACT

This present research work focuses on the valorization of pig manure for production of biogas from the urban commune of N'Zérékoré. A comparison between modern and local pig manure is done in order to understand which one produces more biogas in nomo-digestion. It was carried out in January 2023 from 3 to 28/01/2023 in the Physics laboratory of the University of N'Zérékoré. Before digestion process, the following physicochemical parameters of the two type of pig manure were determined thanks laboratory analysis: density, dry matter rate, organic matter rate and carbon content. The anaerobic digestion process took 26 days in ambient temperature of 25°C. Three digesters (D1, D2 and D3) of each pig manure type (modern and local) were loaded on 03/03/2023. The first one with 5 kg of pig manure diluted in 10 liters of water, the second digester with 5 kg of pig manure diluted in 8 liters and the last one with 5 kg of pig manure diluted in 6 liters, all them in mono-digestion. The average value of physicochemical parameters for the two type of pig manure computed and showed it is modern pig manure which contains more organic matter and carbon content. The main results obtained after digestion for modern pig manure are: a) the average biogas productions 1.52 liters for (D1); 3.28 liter for (D2) and 2.82 liter for (D3). The cumulative amounts of biogas respectively: D1 (39.75 liters), D2 (85.50 liters), D3 (73.50 liters). The total cumulative production is 198.75 liters at the end of the process. For local pig manure the average biogas productions is 0.30 liters for (D1) and the cumulative amounts of biogas is 7.95 liters. The comparison of digesters D1 between the two type of pig manure (modern and local) in terms of daily biogas production, daily cumulative biogas production and the average biogas production illustrated the modern pig manure is the most productive. The novelty of this research work is that this model perform the comparison of modern pig manure and the local one in biogas production. The combustibility test showed the biogas produced during the first week was no combustible (contains less than 50% methane). Combustion started from the biogas produced from the 15th day and it is from the 20th day that a significant amount of stable yellow/blue flame was observed. The results of this study show the combination of pig manure and cow dung presents advantages for optimal biogas production.

Keywords: Production, Biogas, Pig Manure, Modern, Local, Model, Comparison, N'Zérékoré

INTRODUCTION

Today's societies demand the existence of continuous, sustainable and economic energy necessary for any economic development and growth [1]. This demand finds its response in the use of renewable energies. Biogas is a source of renewable energy, similar to solar, wind, and geothermal energy [2].

Since the beginning of the industrial development, human activities have contributed considerably to the increase in the concentration of Greenhouse Gases (GHG) in the atmosphere. The breeding sector is one of the activities that have a strong impact on the natural environment, with the emission of the three main GHGs (CO2, CH4 and N2O). CH4 represents nearly 44% of these emissions [3-4].

In 2011, the European Union issued a directive to reduce GHGs from 80 to 95% by 2050 in order to limit global temperature rise to a maximum of 2°C. To achieve this objective, current fossil energy vectors must be replaced by renewable energies, such as biogas [5- 6]. Biogas is a flammable gas generated from the anaerobic digestion (AD) of organic matter, which includes animal-human excrement, kitchen-agricultural residues, industrial and municipal waste [7]. It is mainly composed of methane (50 - 70%), carbon dioxide (20 - 40%) and traces of other gases (Nitrogen, Hydrogen, Ammonia, Hydrogen sulfide, etc.) [8]. The calorific value of biogas varies between 485 and 679 kWh/m3, its combustion temperature is between 800°C and 1100°C [9]. Biogas has several advantages compared to the other renewable energy sources, including its easy accessibility and economical aspects [10-11-12]. In addition to waste treatment and reducing fossil fuel consumption, biomethanization has additional benefits for households practicing agriculture and breeding. This is particularly the case in many rural communities in the Republic of Guinea [13-14-15]. Valuation of these animal droppings could be considered as an economical and ecological solution [3]. Environmental, cultural and socio-economic conditions favor pig breeding in Forest Guinea and in particular in the urban commune of N’Zérékoré. This breeding produces a large quantity of droppings and slurry every year, whose valuation remains a major problem [16]. Assessment of the energy potential of pig manure for the production of biogas in the urban commune of N’Zérékoré in Guinea has been recently done [17] The combination of several or-ganic materials (co-digestion) for the production of biogas is a technique favorable to microbial flora [18]. The physicochemical parameters of methanizable waste have an influence on the yield and composition of biogas [19]. This paper propose a bio-gas production model from pig manure in mono digestion in the urban commune of N'Zérékoré A comparison is made between biogas produced by pig manure from modern breeding and from local breeding. To achieve this objective we proceeded: a) to pig manure physico-chemical parameters determination (humidity, dry matter rate, organic matter rate and carbon content), b) to the design of experimental biogas production devices (biodigesters and accessories), c) to the substrates preparation, d) to the loading of the biodigesters with substrate, e) to the monitoring of the parameters (daily and cumulative production for the two type of pig manure) and finally, to carry out a comparison in terms of biogas production between the two type of pig manure (from modern and local breeding). This paper is organized as follows. After the introduction section above, the Materials and Methods section is presented in which a description of the study zone is first presented followed by the pig manure pysicochemical parameters determining and the experimental devises allowing biogas production. At the end the Results and Discussion Section is presented.

MATERIALS

Study area

The Prefecture of N'zérékoré is one of the 33 prefectures of Guinea. It is the largest city in Forestry Guinea, a region in the southeast of the Republic of Guinea. The city is also the capital Forest region. It is located between 7°32 and 8°22 north latitude and 9°04 west longitude and extends over 47.3 km2. The distance to neighboring prefectures is 39 km for N'Zérékoré-Lola, 62 km for N'Zérékoré-Yomou, 125 km for N'Zérékoré-Beyla, 135 km for N'Zérékoré-Macenta. Nzérékoré is at an elevation of 480 m and its relief is rugged. The plateau is dominated by hills that are sometimes gneissic (Gonia) and sometimes quartz (Gboyéba). The city has three important mountains: Götö (450 m), Hononye and Kwéléyé (350 m). Sheep breeding, goats and pigs is practiced throughout the commune. The pig herd is the largest in all areas of the N’Zérékoré. Cattle are imported from neighboring communes intended directly for butchery. The Map of the urban commune of N’Zérékoré is in Figure 1.

Fig.1: *Map of the urban commune of N’Zérékoré*

Tools and materials

To carry out this research, we used the following materials and equipment: plastic bottles, plastic flasks, cooler, gloves, graduated containers, electronic balance, analytical balance, valves, flexible pipes, clamps, liquid glue, Teflon, pH meter and temperature sensor. [17-20].

METHODS

Pig manure physico-chemical parameters determining

Sampling procedure

The samples were collected at the N'Zérékoré city on 01/03/2023 and transported in airtight polypropylene bottles to the laboratories of the Guinean Society of Oil Palms and Rubber Trees of Diécké where they arrived on 01/04 /2023. These sam-ples consist of pig manure (modern and local breeding). The gravimetric method was used to determine the following physico-chemical parameters: The humidity rate H (%), the dry matter rate DM (%), the organic matter rate OM (%) and finally the or-ganic carbon rate C (%).

Humidity and Dry matter

For the two (2) types of analysis, we took an average of 5g of sample and placed them in five previously tared petri dishes and brought them to the oven set at 105°C for three hours. Afterwards, remove them using metal tweezers, then place them in the desiccator for cooling and carry out the final weighing. Then humidity expression is

$$H\ (\%) = \frac{P_3}{P_2 - P_1} \times 100$$

Where, P1 is the weight of the empty petri dish in grams, P2 the weight of the petri dish and the sample in grams before drying and P3 the weight in grams of the petri dish and the weight of the sample dried at 105°C for 3 hours.

Organic Matter rate and Carbon Content

The material obtained in the determination of humidity is introduced into a previously tared crucible and brought to the muffle furnace for calcination. After the calcination time which is 2 hours, the sample is removed and placed in the desiccator for cooling. Finally, the last weighing is carried out and the residue obtained is generally represented by the mineral part of the test portion. The organic matter rate is calculated by the following expression

$$OM\ (\%) = \left[\frac{(P_c + E) - P_{500}}{(P_c + E) - P_{cv}}\right] \times 100$$

Where, OM is the organic matter rate, P_c+E is the weight of crucible and sample before calcination, P_{500} is the weight of the crucible and the sample after calcination in a muffle furnace at a temperature of 500°C for 2 hours and P_{cv} the weight of empty crucible.

From the proportion of organic matter thus determined, the percentage of carbon contained in the sample is calculated using the following expression

Experimental devices and set up

For the design of the digester (D), we used a plastic bottle of 20 liters and 280g empty mass with two others of the same volume, one of which is considered as a gasometer filled with water and the other empty to collect the water which is emptied from the gasometer under the pressure of the biogas produced. They are graduated in centiliter using graph paper in order to quantify the gas produced. Three (3) digesters were designed in this experiment. The device for the three different types of substrates is represent in (Figure 2).

Substrates preparing

The experiment was carried out at the Physics laboratory of the University of N'Zérékoré from 3 to 28/01/2023. Loading of experimental digesters with substrates began on 03/12/2020. Each of the 3 digesters was filled with substrates of different composition. Table 1 indicates the composition of the substrates of the 3 digesters

Table -1: Proportions for the different digesters

Pig manure proportion in %	Pig manure mass	Water volume	Digester code
100% pig manure	5kg	10 liters	D1
100% pig manure	5kg	8 liters	D2
100% pig manure	5kg	6 liters	D3

Measurement of daily and cumulative biogas production

The daily and cumulative biogas production of each type of substrate was measured on the gasometer graduation (Figure 2)

Fig.2: *Experimental devices*

RESULTS AND DISCUSSION

In this section we will first show the results of pig manure physicochemical parameters determination for the two types of pig breeding (modern and local breeding). Secondly the cumulative biogas production is presented for the two type of pig manure substrate (modern and local breeding) in order to find out which one produces more biogas. And finally the combustion test of the biogas produced by the two type of pig manure substrate is performed in order to compare the biogas quality of the pig manure (modern and local breeding).

Pig manure physico-chemical parameters results

Abbreviations should be defined at first mention in the abstract and again in the main body of the text and used consistently thereafter.

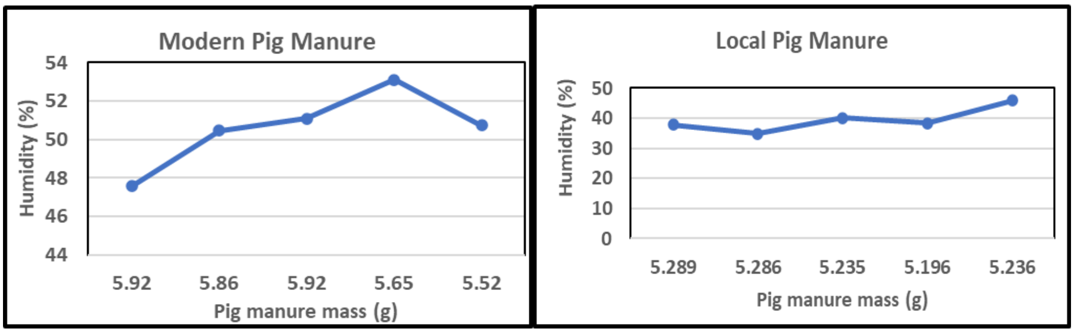
Humidity and dry matter

Based on the expression (1), the humidity and dry matter rate for the two type of pig manure are presented in the below Table 2

Table -2: Humidity and dry matter rate

Pig manure type	Sample	P1	P2	PE	P3	H (%)	DM (%)
Modern pig manure	E1	17,1285	23,0485	5,92	20,2366	47,5777	52,4223
	E2	17,4812	23,3412	5,86	20,3846	50,4539	49,5461
	E3	17,709	23,629	5,92	20,6038	51,1013	48,8987
	E4	17,601	23,251	5,65	20,251	53,0973	46,9027
	E5	17,6253	23,1453	5,52	20,3453	50,7246	49,2754
Average		17,509	23,283	5,774	20,3642	50,5909	49,4090
Local pig manure	E1	16,805	22,094	5,289	20,094	37,8143	62,1857
	E2	16,4512	21,7372	5,286	19,8972	34,8089	65,1911
	E3	16,776	22,011	5,235	19,911	40,1146	59,8854
	E4	16,4251	21,6211	5,196	19,6311	38,2986	61,7014
	E5	16,285	21,521	5,236	19,121	45,8365	54,1635
Average		16,548	21,7968	5,2484	19,7308	39,3745	60,6254

Figure 2 and 3 gives the comparison of the humidity and dry matter rate respectively between the two type of pig manure (modern and local breeding).



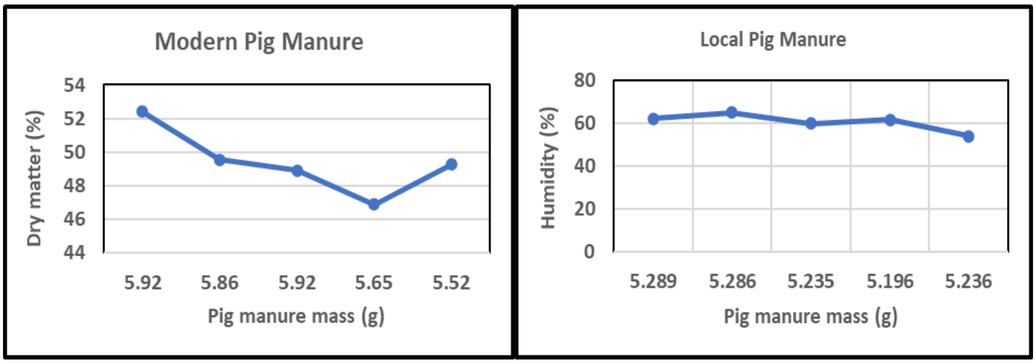


***Fig. 3**: Dry matter rate, comparison between Modern pig manure (a) and local pig manure (b)*

From Figure 2 and 3 we can see the modern pig manure has the highest humidity level (Figure 2), while local pig manure has the highest dry matter content (Figure 3)

Organic matter rate and Carbon content

From the expression (2), the organic matter rate and carbon content for the two types of pig manure are presented in the Table 3.

Table-3: Organic matter rate and carbon content

Pig manure type	Sample	Pcv	PC + E	P500	OM (%)	C (%)
	E1	17,1285	20,2366	17,6646	82,75	47,99
Modern pig manure	E2	17,4812	20,3846	17,4636	100,60	58,35
	E3	17,709	20,6038	17,7326	99,18	57,52
	E4	17,601	20,251	17,4	107,58	62,40
	E5	17,6253	20,3453	17,4323	107,09	62,11
Average		17,509	20,3642	17,5088	99,44	57,67
Local pig manure	E1	16,805	20,094	18,2648	55,61	32,25
	E2	16,4512	19,8972	18,0548	53,46	31,00
	E3	16,776	19,911	18,2035	54,46	31,58
	E4	16,4251	19,6311	17,7296	59,31	34,40
	E5	16,285	19,121	17,1289	70,24	40,74
Average		16,548	19,7308	17,8763	58,61	33,99

Figure 4 and 5 gives the comparison of the organic matter rate and carbon content respectively between the two type of pig manure (modern and local breeding)

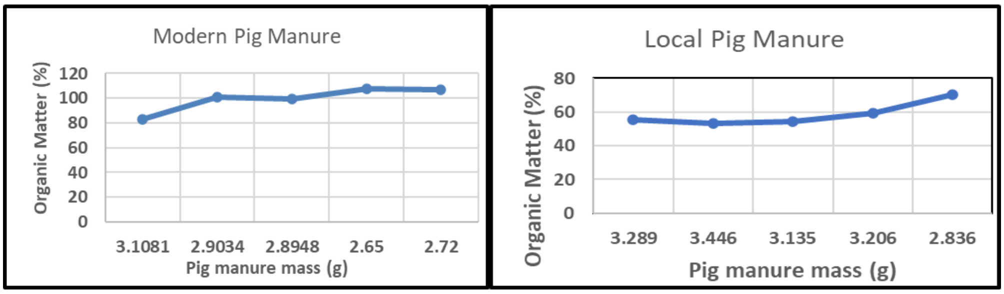


***Fig.4:** Organic matter rate, comparison between Modern pig manure (a) and local pig manure (b)*

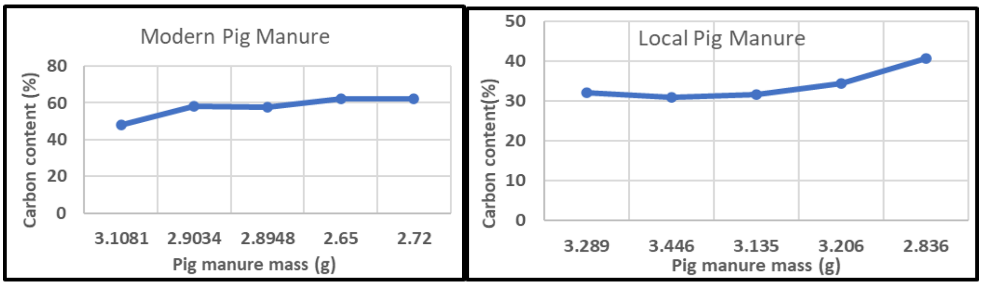


***Fig. 5**: Carbon content, comparison between Modern pig manure (a) and local pig manure (b)*

We also compared the average values of the physico-chemical parameters of the two types of pig manure (modern and local pig manure). The result indicate the modern pig manure has higher level of carbon content than the local pig manure as showing the Figure 6.

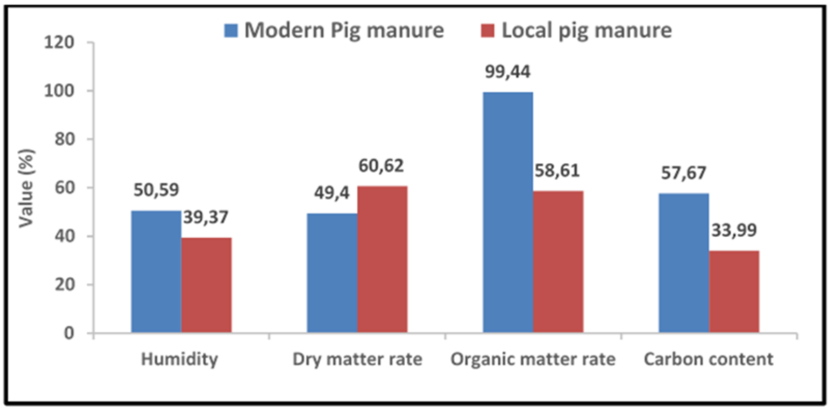


Fig. 6: *Comparison of the average physico-chemical parameters between Modern pig manure (blue color) and local pig manure (red color)*

From the above Figure 6 we can see clearly that it is modern pig manure contains more organic matter and carbon content. It is known that the biogas production is directly linked to the carbon content in the biomass which can indicate us that mod-ern pig manure produces more biogas than local pig manure

Daily biogas production of Modern pig manure

The daily biogas production in the three digesters are showing in Figure 7-9

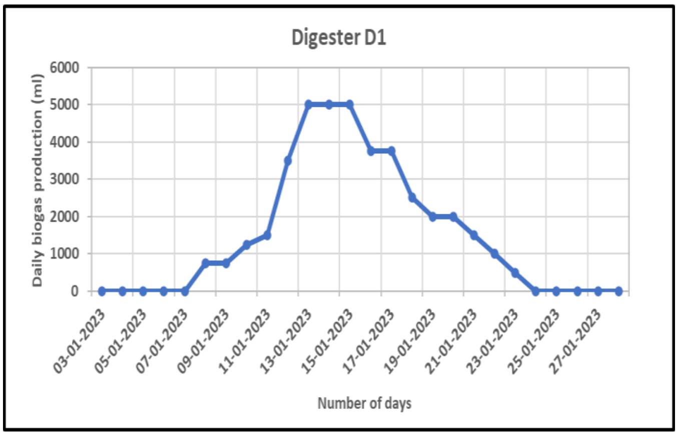


Fig. 7: *Daily biogas production for Digester D1 (5kg pig manure+10 liters of water)*

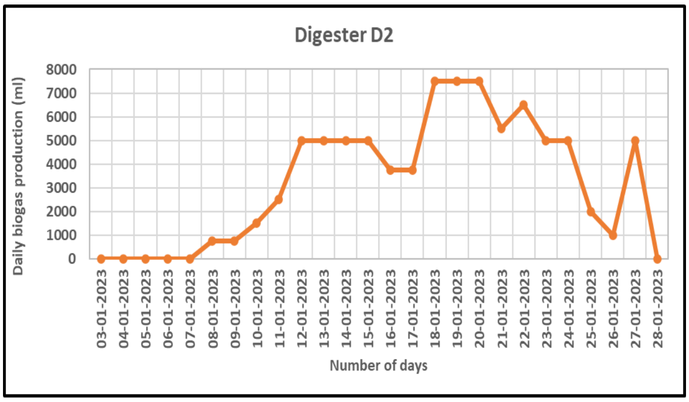


Fig.8: *Daily biogas production for Digester D2 (5kg pig manure+8 liters of water)*

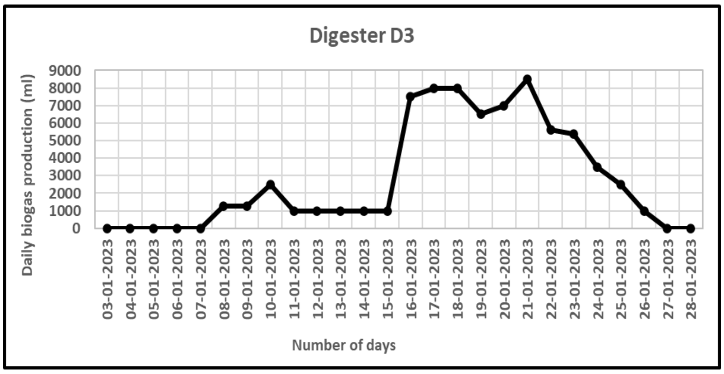


Fig. 9: *Daily biogas production for Digester D3 (5kg pig manure+6 liters of water)*

From Figures 7- 9 we notice the biogas production states at the same day for all the three digesters (07/01/2023) which corresponds to the 5th days. We also notice that the evolution of daily biogas production has the same trend for digestions D1 (Figure 7) and D2 (Figure 8) from the 1st to the 15th day (17/01/2023). However from this date, biogas production continues to decrease until zero for digester D1, while for digester D2 the production increases until its maximum before decreasing to zero. Figure 9 shows that the digester D3 is the most productive with a maximum daily production value equal to 8500 milliliters (8.5 liters) of biogas, followed by digester D3 (Figure 8) with a maximum daily production value of 7500 milliliters (7.5 liters) of biogas and the least productive is digester D1 (Figure 7) with a maximum daily biogas production of 5000 milliliters (5 liters).

Cumulative Biogas production of modern pig manure An Article in a Conference

The cumulative daily biogas production profiles for the three digesters is shown in Figure 10. The curves are all characterized by low biogas production during the first week of digestion (latency phases), then an acceleration in production was noticed from 8th to 24th day (exponential phase) for digesters D2 and D3, and from 8th to 21st for digester D1. Then a stabilization of production from 21st to 26th for digester D1 and from 24th to 26th for digesters D2 and D3 (bearing phase) [21-22-18]. The duration of these different phases depends on the nature of the substrate [23-24]. Latency phase: is the first phase (substrate liquefaction period). It corresponds to the progress of hydrolysis, acidogenesis and acetogenesis. In the present study, it lasted: 7 days for all the digesters, with a production of 1.5 liters for digesters D1 and D2, and 2.5liters for digester D3. Exponential phase: is the second phase, which corresponds to methanogenesis. It lasted: 16 days (from 8th to 24th day) for the substrate in D2 and D3; 13 days (from 8th to 21st day) for the substrate in D1. Bearing phase: is the third phase, it corresponds to a stabilization of the biogas production under the effect of substrate depletion. It starts respectively from the 21st day for the substrate in D1 and from the 24th day for digesters D2 and D3.

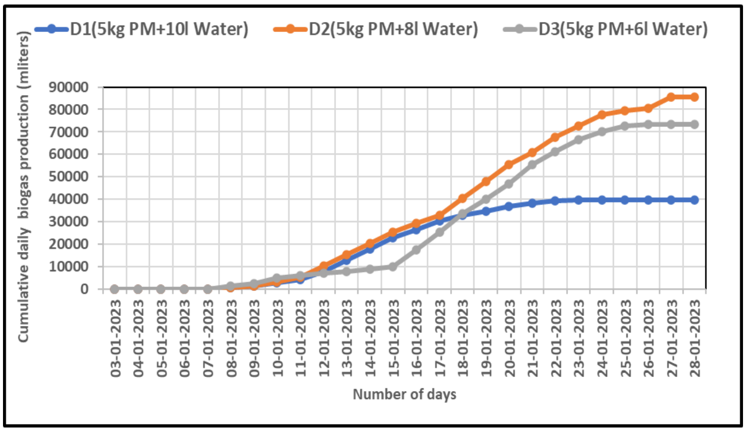


Fig.10: *Cumulative daily biogas production profiles*

The diagrams in Figure 11 shows the cumulative biogas production during the 26 days digestion for the substrates of the three digesters.

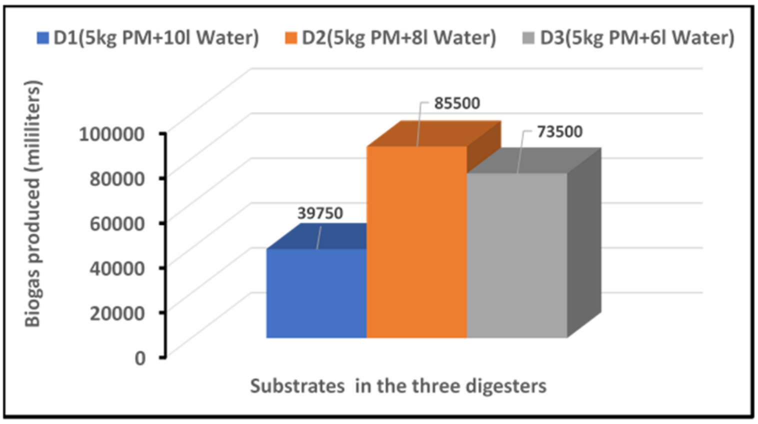


Fig. 11: *Cumulative biogas production of substrates in the digesters*

The cumulative production of biogas are: D1 (39.75 liters), D2 (85.50 liters), D3 (73.50 liters) (Figure 11). The cumulative production total is 198.75 liters. It appears from these results that the substrate of digester D2 (5kg pig manure + 8 liters water) has the highest cumulative value of biogas products (85.50 liters) following by D3 (5kg pig manure + 6 liters water) with 19, 65 liters showing thus best mixture of pig manure with water for substrate preparation is 5kg pig manure and 8 liters of water in our study

Comparison between modern Pig manure and Local Pig manure in Biogas Production

To compare the efficiency in terms of biogas production between modern pig manure and local pig manure, we compare the biogas production result of digester D2 for the two type of pig manure. Figure 12 and Figure 13 illustrate the comparison respectively of daily biogas production and cumulative daily biogas production be-tween modern pig manure and local pig manure from digester D2 (5kg pig manure + 8 liters water).

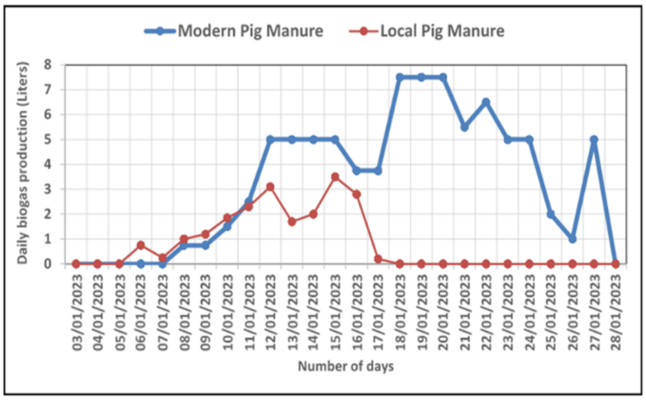


Fig.12: *Daily biogas production: comparison between modern pig manure and local pig manure*

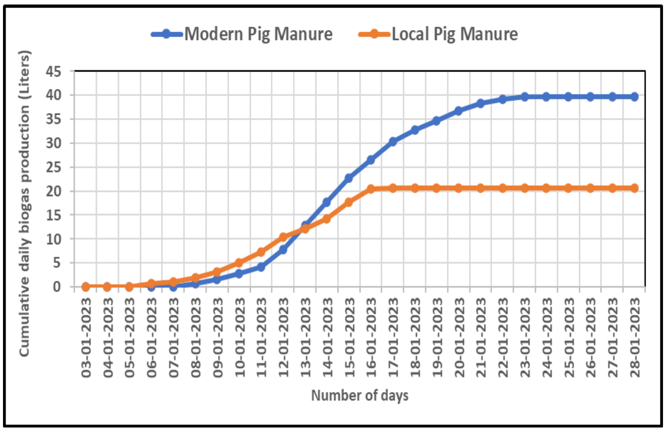
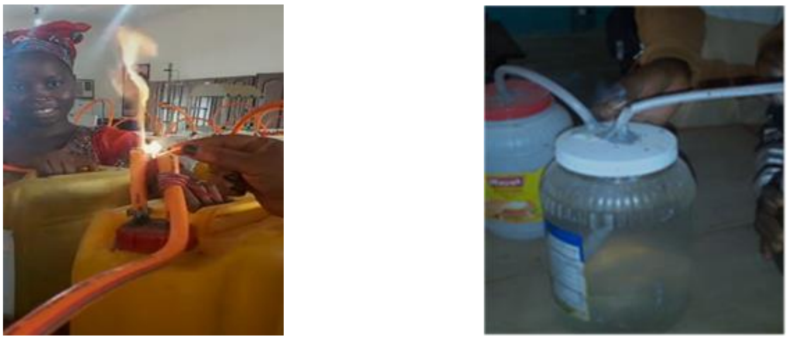


Fig. 13: *Cumulative daily biogas production: comparison between modern pig manure and local pig manure*

We can see from Figure 12 the modern pig manure production of biogas is most important than for local pig manure. The maximum biogas daily production for modern pig manure is 7.5 liters which for local pig manure it is 3.5 liter. The daily biogas production evolution curve for both types of pig manure have almost the trends (Figure 12). However, we founded that the production of biogas for the local pig manure only lasts two weeks from 05/01/2023 to 18/01/2023 while for the modern pig manure the production of biogas starts from 07/01/2023 until 28/01/2023 or three weeks.
From Figure 13 the two curves have the same trends until 16/01/2023, while from 16/01/2023 to 28/01/2023 the cumulative biogas daily production continue for modern pig manure and becomes constant for local pig manure.

Biogas combustion test

Biogas is composed mainly by methane CH4 and others gas like (CO2, N2 and O2).It becomes a combustible gas if the methane content is greater than or equal to 50%. The combustion of biogas is materialized by the release of a yellow or blue flame depending on the methane content. A consistent blue flame confirms the existence of methane in important proportion (50%) or more [28].
The combustibility test shows the biogas from the local pig manure is must combustible than that from the modern pig manure (Figure 14).



a) Biogas from local pig manure b) Biogas from modern pig manure

***Fig.14:** Biogas combustion test*

CONCLUSION

This research allowed us to perform an experimental production model of biogas from pig manure. Comparison of the average values of physico-chemical parameters (Humidity, dry matter, organic matter and carbon content) between modern pig manure and local pig manure was performed. It was founded the modern pig manure has the highest humidity level (50.59%), and (39.37%) for local pig manure. However the local pig manure has the highest dry matter content (60.62%) against (49.4%) for modern pig manure. We also compared the average values organic matter and carbon content for the two types of pig manure (modern and local pig manure). The result indicate the modern pig manure has higher level of carbon content (57.67%) and organic matter (99.4%) than the local pig manure (33.99%) and (58.61%) as showing the Figure 6.
Afterwards the daily biogas production of Modern pig manure results for the three digesters were presented and had shown that the digester D3 is the most productive with a maximum daily production value equal to 8.5 liters of biogas, followed by digester D3 (Figure 8) with a maximum daily production value 7.5 liters of biogas and the least productive is digester D1 (Figure 7) with a maximum daily biogas production of 5 liters.
After, we compare the biogas production result of digester D2 for the two type of pig manure in order to compare the efficiency in terms of biogas production between modern pig manure and local pig manure. The following results are founded: the modern pig manure production of biogas is most important than for local pig manure. The maximum biogas daily production for modern pig manure is 7.5 liters which for local pig manure it is 3.5 liter. The daily biogas production evolution curve for both types of pig manure have almost the trends (Figure 12). However, we founded that the production of biogas for the local pig manure only lasts two weeks from 05/01/2023 to 18/01/2023 while for the modern pig manure the production of biogas starts from 07/01/2023 until 28/01/2023 or three weeks
Finally, the combustibility test was performed and shown the biogas from the local pig manure is must combustible than that from the modern pig manure (Figure 14).

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