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RESEARCH ARTICLE

EVALUATION BY METHANIZATION OF THE BIOGAS POTENTIAL OF THE CORN COB IN THE PREFECTURE OF KINDIA, GUINEA

Yacouba Camara[1], Amadou Lamarana Bah[2] and Boureima Kabore[3,4]

1. InstitutSupérieur de Technologie de Mamou, DépartementEnergétique, BP 63, Mamou, Guinée.
2. Université Gamal Abdel Nasser de Conakry, Laboratoired'Enseignement et de Recherche enEnergétiqueAppliquée, BP 1031, Conakry, Guinée.
3. UFR-ST, Université Norbert ZONGO, Koudougou, Burkina Faso.
4. Laboratoired'EnergiesThermiquesRenouvelables, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso.

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Abstract

The objective of this research is to evaluate the energy potential of cow dung and corn cob inputs, with a view to their valorization. The research made it possible to determine the characteristics of the physicochemical parameters of cow dung and corn cob. The results obtained in terms of cow dung are: Humidity (79.17%), Dry Matter (20.83%), Organic Matter (OM) 57%, density (208.33 kg/m3), Carbon rate 32.53%, Nitrogen rate (1.82%) and the C/N ratio (21.30) and those of the corn cob, Humidity (38%), Dry Matter (62%), Organic Matter (67%), Density (250 kg/m3), Carbon rate (39.7%), Nitrogen rate (2.55%) and C/N ratio (15.23). These results compared to those in the literature revealed a very good coincidence. Two experiments on the methanization of these inputs were carried out, the anaerobic digestion lasted 27 days, in a temperature range of 27°C to 31°C (mesophilic range). It was obtained for: corn cob 28.4 liters, cow dung 22.6 liters and for co-digestion 38.7 liters. In perspective, we recommend the continuation of these studies.

Introduction:-

The fight against global warming involves the development of renewable energies such as wind, solar, geothermal, biomass, etc. according to the objectives set within the framework of "Renewable Energy for All" [1-5]. Among renewable energies, biomass (e.g. wood and agricultural and municipal waste) has high potential due to its availability and renewable nature and is expected to play a notable role in global energy supply [6], [7], [8], [9]. The high potential for energy recovery from agricultural biomass waste has motivated governments to promote alternatives to environmentally harmful total incineration to convert the energy contained in waste into a useful form [[10], [11], [12]]. A wide variety of biomass wastes have been used for biofuel production such as rice husk and straw, wheat straw, pistachio shell, and corn stalks and leaves [13]. As an important raw material of biomass energy, agricultural waste is a misplaced resource with great potential [14-15].

The development of renewable energies is essential to the extent that non-renewable fossil energies are becoming rarer but also and above all because of the growing demand for energy. These fossil fuels have a negative impact on our environment. It is also important to remember the enormous positive impact that agriculture plays in reducing

Corresponding Author:- Yacouba Camara
Address**:-** InstitutSupérieur de Technologie de Mamou, DépartementEnergétique, BP 63, Mamou, Guinée.

carbon dioxide in the ecosystem, through the phenomenon of photosynthesis. This is why developing and promoting renewable energies in general, and biomass in particular, is becoming a priority for their numerous environmental and energy advantages. Modern biomass remains little used in Africa, due to a lack of reliable data on their availability and methods of valorization. Around 85.7% of the population of the member states of the Economic Community of West African States (ECOWAS) use solid fuels (mainly wood and charcoal), for cooking (traditional valorization of biomass) according to the Institute of Energy and Environment of the Francophonie (IEEF) according to a progress report on renewable energies and energy efficiency of ECOWAS [16]. In 2014, ECOWAS member states had only 3.5 MW of biomass energy capacity installed and connected to the grid. However, Africa has an enormous quantity of agricultural biomass that has not yet been exploited. Indeed, most African economies are based on agriculture. This generates an enormous quantity of unused agricultural biomass based on the inventory of agro-industrial by-products in West Africa [17]. This form of energy source can play a key role in improving the rate of rural electrification as long as the raw material is available, nearby and at low cost. Agricultural biomass is, for the most part, a dry biomass for which a possible valorization would be thermochemical conversion (pyrolysis, combustion, carbonization and gasification). This type of conversion considerably increases the recoverable energy potential of biomass. This conversion aims to produce a gas mixture used as fuel in a gas turbine for the production of electrical energy and/or heat. Guinea, a West African country, is characterized by relatively low energy consumption, with the traditional abusive use of biomass energy used in an unsustainable manner.

Biomass is put on the back burner, due to the absence of a reliable database to promote its valorization. The share of renewable energies in the total final energy consumption of the “Economic Community of West African States” (ECOWAS) region is relatively marginal, even if it varies greatly from one country to another. According to the Global Monitoring Framework of the “Sustainable Energy for All” initiative, Guinea-Bissau, Ghana and Sierra Leone occupied in 2010 the first three regional places for the contribution of renewable energies to final consumption with 30, 3%, 22.4% and 19% respectively. Their positioning was mainly due to the use of the resource called "modern biomass" according to the progress report of the Institute of Energy and the Environment of the Francophonie (IEEF) on renewable energies and energy efficiency of ECOWAS [17]. Better still, the Regional Center for Renewable Energy and Energy Efficiency (ECREEE), in partnership with the governments of member states, focused on the role that renewable energy technologies play in improving production. electricity and access to electricity across the region. In this context, mastery of technologies relating to the energy recovery of biomass in Africa is essential. This will contribute effectively to the promotion of biomass energy in Africa, a form of energy which until now remains poorly known and poorly exploited to the detriment of solar energy, which is more widely used and developed. Faced with the low electrification rate in general, at the national level and in rural areas in particular, and given the increasingly large quantity of non-recycled agricultural residues recorded, biomass proves to be the best indicated not only based on its availability, but also its ease of conversion into usable energy in developing countries. It solve two major problems in developing countries : waste management, which is becoming more and more cumbersome, and the resolution of the energy crisis, through rural electrification. Regarding energy from biomass, there are different types of recovery, namely: thermal recovery, chemical recovery, biological recovery and thermochemical recovery. However, we will be particularly interested in the thermochemical aspect of the valorization of biomass, taking into account its optimal yield and its adaptation to agricultural waste from tropical countries, and their physicochemical characteristics. Guinea is one of the countries in the West African sub-region whose economy is strongly dominated by agricultural production. The numerous efforts made in this area, accompanied by the mechanization of agriculture, are further improving agricultural yield. Also, new crops have emerged in impressive quantities during their harvest, thus generating residues which can be used for energy purposes.

Guinea has considerable potential in agricultural and household waste that can be converted into energy. Feasibility studies on biomass show that global waste management would significantly reduce fossil energy imports. However, there are no reliable statistics on the availability and nature of agricultural residues that can be recycled. Furthermore, few data relating to the physicochemical characterization and kinetics of any agricultural biomass are currently available. This present research deals with the biochemical conversion of agricultural biomass by methanization for the production of biogas, through a continuous biodigester.

Materials and Methods:-

Materials:-

Presentation of the study area

Kindia prefecture is located between 10 3’29” north latitudes and 12 52’08” west longitudes. It has an area of 9,115 km^2, a population of 469,446 inhabitants (2016), density 52 inhabitants/km^2. It is subdivided into 11 sub-prefectures which are :Kindia-center, Bangouyah, Damakanyah, Friguiagbé, Kolenté, Madina-Oula, Mambia, Molota, Samayah, Sougueta and Linsan.

Located in maritime Guinea in the Kindia region, it is limited to the East by the Prefecture of Mamou, to the West by the Prefectures of Dubréka and Coyah, to the North by the Prefectures of Pita and Telimelé, to the South by Sierra Leone, to the North-East by the prefecture of Dalaba and to the South-West by Forécariah.

It has a relief made up of plateaus whose average altitude is 400 m with Mount Gangan (1117 m) as its highest point. The climate is humid tropical with two seasons of equal duration. The average rainfall is 2500mm spread over approximately 150 rainy days.

The average annual temperature is 25°C, the average relative humidity varies from 93% (wet season) to 51% (dry season). The prevailing winds are the monsoon and harmattan. The vegetation is made up of wooded savannahs, wooded savannahs and classified forests which are :Kourédi, Séguéya, Kombitidé, and Koukou park.

Tools

To set up the experimental device, the following equipment was used :

1. Drying and calcination ovens, power 800W ;
2. The DIAL-O-GRAM brand analytical balance (2610g) ;
3. The glass stirrer (agitation and homogenization of the substrate) ;
4. Tongs (allow handling of hot glassware) ;
5. The test tube, (for reactions of small quantities of reagents) ;
6. The beaker, cylindrical container (for measuring volume).

Methods:-

The methodologies used to carry out this research are based on the characterizations of the substrates used for the experiment. These characterizations are defined as follows:

A) Numerical method

a) Density

A container of 1 liter volume is filled with organic waste (animal inputs) without compaction and weighed on a balance. The average density was calculated from the relationship :

$$\rho = \frac{m}{v} \qquad (1)$$

Or :

$\rho -$ Density in kg/m^3 ;
m- Mass in kg ;
V- Container volume in m^3.

b)Relative humidity of the substrate

The majority of protocols determine humidity by drying at a temperature of 105°C to a constant weight.

The percentage of humidity of the different organic waste is determined by the difference in weight of the sample before and after drying until the mass stabilizes by the following expression [17]:

$$H(\%) = \left[\frac{M_O - M_{Sec}}{M_O}\right] \times 100 \qquad (2)$$

Or : M_o is the initial mass of the sample, M_{sec} the mass of the dried sample.

The dry matter rate was determined by the relationship (3).

$$MS\ (\%) = 100 - H(\%) \qquad (3)$$

c) Organic Matter Content (OM)

Methodology: The determination of the level of Organic Matter (OM) at the level of each substrate consists of weighing 20 g of each substrate which is placed in the oven for 24 hours at 70°C, then the calcination of 3 g of the samples, previously dried for 2 hours in the incinerator. The Organic Matter content is determined, according to equation (4) [18] :

$$MO(\%) = \left[\frac{M_{sec} - M_{SI}}{M_{Sec}}\right] \times 100 \quad (4)$$

With, M_{sec}, the weight of the substrate before calcination (g), M_{SI} the weight after calcination (g).

d) Mineral matter

Methodology: After 6 hours in the incinerator, we obtain an inorganic residue. This mass of waste calcined at 600°C (MSI) is the mineral material. Measuring the weight of the residual ash fraction by the loss on ignition allows us to determine the percentage of the mineral fraction contained in the waste [18].

This mineral matter is determined by relation (5) :

$$MM(\%) = \left[\frac{M_{SI}}{M_{Sec}}\right] \times 100 \quad (5)$$

Or :
MS- Mass of dry matter ;
MM- Mass of mineral matter ;
MSI- Mass of incinerated material.

a) Carbon (C)

Methodology: From Organic Matter (OM), a deduction of the carbon content is possible by one of the following relationships (6) [19].

$$C(\%) = \frac{MO(\%) - 1,5}{1,4} \text{(NT)} \quad (6.a)$$

$$C(\%) = \frac{MO(\%)}{1,725} \text{(NF)} \quad (6.b)$$

$$C(\%) = \frac{MO(\%)}{2} \text{(NB)} \quad (6.c)$$

Or :
C(%) : Total carbon ;
MO (%) : Organic material.

So we took the average of the three methods to find the carbon content.

f) Nitrogen Rate (N)

Methodology: Total nitrogen is determined by the Kjeldahl method following two steps, namely:

- mineralization of the 1g mass sample with concentrated sulfuric acid in the presence of a catalyst (copper sulfate plus sodium sulfate) for two (2) hours;
- distillation and titration of the ammonia released in the last step using a sulfuric acid solution with a concentration equal to 0.02 normal.

The total Kjeldahl nitrogen is given by relation (7) [20]:

$$N(\%) = V_{Titration} \times 0,195 \times Masse \text{ de prise d'éssai} \quad (7)$$

B) Experimental studies (Methanization)

After characterizing the samples, we carried out methane production experiments from cow dung and corn cobs. These experiments took place at the Applied Energy Teaching and Research Laboratory (LEREA) of the Gamal Abdel Nasser University of Conakry (UGANC) in the Republic of Guinea. They aim to compare the fermentation of different substrates (cow dung and corncobs and co-digestion).

Description of the digester

a). Materials

During this study we used the following materials: Cans (2), valves, flexible pipes, clamps, liquid glue, Teflon, inner tube (2).

b). Experimental method

This research concerns the determination of the quantity of biogas contained in 5 kg of each type of substrate (cow dung and corncob) and the mixture of the two substrates (codigestion) in the proportion of one (1) kg each.

During this experimental study, we simultaneously used two 20-liter plastic drums as digesters; they were filled to 3/4 of their volume respectively with the two types of substrate and their mixture. These samples were diluted in 2 liters of water each. These two digesters were each connected to an air chamber (gasometer) via flexible pipes with an internal diameter of 8 mm. The tightness of the entire system has been checked.

c) Substrate degradation rate

The rate of degradation of a substrate is calculated from the volume of biogas (or methane) produced, compared to the theoretical production of biogas in liter/kg. It results in the following relationship:

$$D_{sub} = \frac{V_{Biogaz}}{V_{Théorique}} \times 100 \qquad (8)$$

The different characteristics were determined by these methods, and the production of methane from the three samples: cow dung, chicken droppings and co-digestion.

Results And Discussion:-

Presentation of the results

The results obtained during this research are presented as follows:

Results of physicochemical characterization of inputs

The corn cob samples were taken from the field of Mr. Aboubacar CAMARA and the cow dung in the Sub-Prefecture of Friguiagbe Prefecture of Kindia, on May 22, 2022. The physicochemical characterization of the inputs was carried out at the Laboratory of Microbiology analysis of the National Quality Control Office (ONCQ) of Matoto Commune in Conakry.

Physical parameters

The physicochemical parameters of the substrates were determined on 3g samples of each type of substrate. Tables (3.1) and (3.2) give the results obtained for humidity, dry matter and density for five samples of each substrate.

Table 3. 1:- Physical parameters of cow dung.

Samples	**Physical parameters**				
	Mass (M_o) g	Mass (M_{sec}) g	Humidity (%) H	Dry matter (%) MS	Volumic mass kg/m^3
1	3	2,25	25,00	75,00	1000,00
2	3	2,2	26,66	73,34	750,00
3	3	2	33,33	66,67	666,67
4	3	1,45	51,66	48,33	500,00
5	**3**	**0,625**	**79,17**	**20,83**	**208,33**

Table 3. 2:- Physical parameters of the corn cob.

Echantillons	**Paramètres physiques**				
	Mass (M_o) g	Mass (M_{sec}) g	Humidity H (%)	Dry matter (%) MS	Volumic mass kg/m^3
1	3	2,63	33,00	87,00	333,00
2	3	2,44	34,00	82,00	291,67
3	3	2,25	36,00	75,00	270,83
4	3	1,55	40,33	51,67	208,33
5	**3**	**1,88**	**38,00**	**62,00**	**250,00**

We notice in Table (3.1) and (3.2) that cow dung and corn cob have an appreciable dry matter content. The densities are 106.3 kg/m^3 for cow dung and 250.00 kg/m^3 for corn cob.

The values of humidity, dry matter, density and organic matter (OM) are given in table (3.3).

The OM rate for each substrate was determined following the calcination of previously dried samples (0.625g for cow dung and 1.5g for chicken droppings) in a muffle furnace, for 6 hours, at a temperature of 600°C. The cremated mass weighed is 0.27 g for cow dung and 0.49 g for corn cob. Using formula (4), we found 57% OM for cow dung and 67% OM for chicken droppings. These results are recorded in Table 3.3.

Table 3. 3:- Physical characteristics of organic waste.

Types inputs	Humidity H (%)	Dry matter MS (%)	Organic matter MO (%)	Volumic mass Kg/m^3
Cow dung	79,17	20,83	57	208,33
corn cob	38,00	62,00	67	250,00

Chemical parameters of cow dung

The chemical parameters (Carbon, Nitrogen, and the C/N ratio) were determined by: Carbon, deduced from Organic Matter (OM), Nitrogen from the Kjeldahl relationship (7) and the ratio (C/N) was calculated. Table 3.4 gives these different parameters and the standards used: Tunisian Standard (NT), French Standard (NF) and Belgian Standard (NB).

Table 3. 4:- Characterization of chemical parameters of cow dung.

Standards	**Chemical parameters**				
	Carbon (C %)	$V_{Titration}$ (ml/g)	Test mass (g/ml)	Nitrogen NT (%)	Report C/N
1 (NT)	46,78	5	1,87	1,82	25,66
2 (NF)	**38,88**	**5**	**1,87**	**1,82**	**21,32**
3 (NB)	33,5	5	1,87	1,82	18,37

The results of the chemical characterization of cow dung show that:

The C/N ratio is equal to 21.32. This value being between 20 and 30 optimums (French Standard), means that the analyzed input can be used for the production of biogas.

Corn cob chemical parameters

Likewise, these parameters were determined for the droppings of laying hens. The results obtained are recorded in table 3.5.

Table 3. 5:- Characterization of chemical parameters of corn cob.

Standards	**Chimical parameters**				
	CarbonC(%)	$V_{Titration}$ (ml/g)	Test mass (g/ml)	Nitrogen NT (%)	Report C/N
1 (NT)	46,78	5	2,62	2,55	18,35
2 (NF)	**38,84**	**5**	**2,62**	**2,55**	**15,23**
3 (NB)	33,5	5	2,62	2,55	13,14

After analysis, the results of chemical characterization of the corn cob show that: the C/N ratio is equal to 15.23. Considering the established standards (15-25 optimum) we deduce that the chicken droppings used can also be used for the production of biogas. The physicochemical parameters obtained for the two substrates are summarized in Table 3.6.

Table 3. 6:-Physico-chemical parameters of cow dung and corn cobs.

Types inputs	Physico-chemical parameters					
	Humidity H (%)	Dry matter MS (%)	Organic massMO (%)	Carbon % COT	Nitrogen % NT	Report C/N	Standards ReportC/N

Cow dung	79,17	20,83	57	38,88	1,82	21,32	20-30
corn cob	38,00	62	67	38,84	2,55	15,23	15-25

In table (3.6) we understand that cow dung, like corn cob, is rich in carbon (38.88% and 38.84%). These two inputs have an organic nitrogen rate of 1.83% and 2.55% with a C/N ratio in accordance with the French standard, 21.32 for cow dung and 15.23 for laying hen droppings. The results obtained demonstrate that these two inputs analyzed can be used for the production of biogas.

Discussions of the results of the physicochemical characterization

The physicochemical parameters of animal effluent from Kindia prefecture show that:

a). The dry matter (DM) rates of cow dung samples (20.83%) and corn cob (62%) are very appreciable according to the literature [21] i.e. (20-50%) for cow dung. cows and (60-70%) for the corn cob.

b). The level of organic matter (OM) in cow dung (57%) is quite close to the result reported by researchers Parra et al. (1977), i.e. (20-67) of MO and for the corn cob (67%) are also close to the results given in [22], i.e. 60-80% of MO.

d). The ratios between the rate of Carbon and Nitrogen (C/N): the results obtained according to our analyzes using the French standard (NF) are respectively 21.83 for cow dung and 15.23 for cow dung. laying hen droppings. These values are very close to the results reported by [22]. According to the literature, we have (20-30) for cow dung and (15-25) for corn cob.

Input experimentation

Two experiments were carried out simultaneously: Cow dung, corn cob and Codigestion (cow dung and corn cob, including 50% for each component). Biogas production began on the 2nd day after loading the digesters and lasted 27 days. The cumulative biogas production for each day is given in table (3.7). The temperature during the experiments was between 27 and 31°C. Table 3.7 gives the different results obtained.

Table 3. 7:- Biogas production.

N°	**Date**	**Days**	**Temperature (°C)**	**Corncobs (L)**	**Roundups+Dung (L)**
1	23/05/2022	0	30^{0}C	0,795	0,73
2	24/05/2022	1	30^{0}C	0,913	0,73
3	25/05/2022	2	26^{0}c	0,924	0,73
4	26/05/2022	3	29^{0}c	0,935	0,73
5	27/05/2022	4	27^{0}c	0,946	0,73
6	28/05/2022	5	25^{0}c	0,968	0,84
7	29/05/2022	6	29^{0}c	0,978	0,84
8	30/05/2022	7	29^{0}c	0,978	0,84
9	31/05/2022	8	30^{0}c	0,978	0,84
10	01/06/2022	9	29^{0}c	1	0,84
11	02/06/2022	10	32^{0}c	1,011	0,90
12	03/06/2022	11	31^{0}c	1,011	0,92
13	04/06/2022	12	27^{0}c	1,021	0,96
14	05/06/2022	13	26^{0}c	1,032	0,96
15	06/06/2022	14	26^{0}c	1,032	0,97
16	07/06/2022	15	28^{0}c	1,043	0,97
17	08/06/2022	16	26^{0}c	1,043	0,93
18	09/06/2022	17	29^{0}c	1,043	0,93
19	10/06/2022	18	28^{0}c	1,054	0,95
20	11/06/2022	19	29^{0}c	1,054	0,97
21	12/06/2022	20	31^{0}c	1,054	0,97
22	13/06/2022	21	29^{0}c	1,064	0,96
23	14/06/2022	22	29^{0}c	1,043	0,96
24	15/06/2022	23	30^{0}c	1,043	0,95
25	16/06/2022	24	25^{0}c	1,011	0,94
26	17/06/2022	25	28^{0}c	1,011	0,88

27	18/06/2022	26	25^{0}c	1	0,84
Average (liter/j)				**0,99**	**0,88**

Figures (3.1, 3.2, and 3.3) show the kinetics of cumulative biogas production from substrates (cow dung, corn cob and co-digestion) during a retention time of 27 days. It should be noted that the scale used for the hydraulic retention time is 1/6.

Figure 3.1 : Corncob Biogas Production

Figure 3.2 : Biogas production from cow dung

Figure 3.3 : Production of Biogas from Corn Cob Cow Dung

Discussions of the results of the experimental study:-

The transformation into gaseous compounds (CO2+CH4) of a defined quantity of the organic substrate occurs as follows: (i) over a period of 27 days, 50% of the total volume of the gas is produced in 09 days with a maximum on the 9th day of fermentation; (ii) the fermentation process continues for all remaining days.

The results of the experimental study of the substrates were carried out at the University of Kindia and showed that biogas production began on the 1st day for codigestion and on the 2nd day for corn cob. After 27 days of methanization in a temperature range of 27°C to 31°C (mesophilic range), the quantity of biogas for the corn cob is 26.98 liters, higher than that of cow dung (22. 6 liters). Codigestion gives a greater value (40.89 liters); on average the specific daily production of biogas from the different inputs is: cow dung (0.50 liter/d), corn cob (0.72 liter/d) and finally co-digestion (0.92 liter/d) at the average temperature of 28°C. The results of the experimental study are recorded in Table 3.8.

Table 3. 8:- Results of the experimental study.

N°	Substrates	Substrate quantity (Kg)	Quantity of biogas (Liters)				
			Results Experience	Results Literature [22]	Gap %	Results Literature [23]	Gap %
1	Corn Cob	2	28,40	40	**11,6**	30	**2,4**
2	Cow dung	2	22,00	20	**-2**	22	**0**
3	Codigestion	2	38,70	-		-	-

These results obtained corroborate with those of Isabelle ZDANEVITCH, et al [22]. Only 11.6% difference for cow dung and – 2% difference for corn cob. It is the same as with M. WAUTHELET, et al [23]. Likewise 2.4% difference for cow dung and 0% difference for corn cob. These slight deviations could be due to environmental conditions (temperature, retention time, etc.) and technical conditions (equipment used).

Conclusion:-

This present research allowed us to achieve the objectives, namely to evaluate the energy potential of the inputs of cow dung and corncobs with a view to their energy recovery. The research allowed us to determine the physicochemical parameters, namely:

a). Cow dung, Humidity (79.17%), Dry Matter (20.83%), Organic Matter (OM) 57%, density (208.33 kg/m3), Carbon rate 38.88%, carbon rate Nitrogen (1.82%) and the C/N ratio is (21.32).

b). Corncob, Humidity (38%), Dry Matter (71%), Organic Matter (67%), Density (250 kg/m3), Carbon rate (38.84%), Nitrogen rate (2. 55%) and the C/N ratio (15.23). The results obtained were compared to those in the literature and revealed very good corroboration.

Two experiments on the methanization of these inputs were carried out, the anaerobic digestion lasted 27 days, in a temperature range of 27°C to 31°C (mesophilic range). It was obtained for : corn cob 28.4 liters, cow dung 22.6 liters and for co-digestion 38.7 liters. In perspective to this research, we have :

1. Evaluate the energy potential of agricultural residues in the Kindia prefecture by determining:
2. Daily production of cow dung;
3. Seasonal production of agricultural residues;
4. The biogas potential of each type of agricultural residue;
5. The quantity and quality of compost that can be produced.
6. Use these resources for the construction of small volume domestic digesters for producers.

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