Biogas potential assessment of animal waste in Macenta prefecture (Republic of Guinea)

Ansoumane SAKOUVOGUI[1], Mamadou Foula BARRY[1], Mamby KEITA[2], Saa Poindo TONGUINO[4]

ansoumane2015@gmail.com[1], intergerbarry@gmail.com[2], mamby1952@gmail.com[3], saapoindo57@gmail.com

[1,2] Higher Institute of Technology of Mamou - Guinea

[3]Department of Physics, Gamal Abdel Nasser University of Conakry - Guinea

[4]Higher Institute Agronomic of Faranah - Guinea

ABSTRACT

This study focuses on the evaluation of the biogas potential of animal wastes in Macenta Prefecture. The census of the three types of herds living in 14 sub-prefectures and the urban commune of Macenta was carried out, of which: 13386 cattles, 17418 pigs and 20005 laying hens. The assessment of daily waste by type of animal was made .The results were 4.23 kg/day of dung per cow; 2.41 kg/d and 2.21 kg/d of pig slurry respectively in semi-improved and local breeding; 0.013 kg/day of droppings per hen. These values made possible to estimate the daily quantities of waste by type of livestock: cow dung (56622.78 kg), pig manure (40967.38 kg) and chicken manure (260.065 kg). The total daily biogas potential of the waste is therefor of the order of 8969.606 m^3, distributed as follows: 6164.427 m^3 for cow dung; 2332.117 m^3 for pig manure and 473.063 m^3 for chicken manure. This potential is distributed by locality and livestock types.

Keywords: *Evaluation, Potential, Biogas, Waste, Animal.*

1. Introduction

Biogas is a colorless and flammable gas produced by anaerobic digestion of animal, plant, human, industrial and municipal waste. It is mainly composed of methane (50 - 70%), carbon dioxide (20 - 40%) and traces of other gases such as Nitrogen, Hydrogen, Ammonia, Hydrogen sulphide, water vapor, etc. [1]. The calorific value of biogas is proportional to its methane content. Under normal conditions of temperature and pressure, with a percentage of methane between 50 and 70% in the biogas, its calorific value varies between 485 and 679 kWh/m^3. The temperature of the combustion flame of the biogas is between 800°C and 1100°C [2].

The evaluation and the valorization of this form of energy from animal waste have several advantages, such as: the elimination of greenhouse gases, the reduction of odors, the obtaining of organic fertilizer, the production of heat and electricity [3].

The biogas potential of the different organic wastes is generally a function of their type, their origin and their physicochemical characteristics such as: Density (Mv), Moisture (H), pH, Dry matter (DM), Volatile Matter (MV), Volatile Carbon (CV), Total Nitrogen (NT), etc. [4]. For some authors [5], the biogas proportions in the organic matter of the waste of each type of livestock are as follows: cow dung (0.948 m^3/kgMV), pig manure (0.841 m^3/kgMV) and dung hen (0.957m^3/kgMV).

In general, Africa faces the problem of low energy consumption, especially in rural areas. Only South Africa consumes 45% of the total electricity produced in Africa, North Africa consumes 30% and Sub-Saharan Africa consumes 24% of the total electricity produced in Africa [6].

In the Republic of Guinea, biomass potential (agricultural residues, agro-industrial waste, domestic waste, plants and animals) represents 80% of the total energy potential of the country. Livestock is after agriculture, the second activity of the rural world. It is a growth sector that contributes substantially to food security and the fight against poverty. It provides 30% income to Guinea's rural areas and contributes 5.6% to the country's Gross Domestic Product (GDP) [7].

The census of the national livestock in 2017 gave: the cattle essentially of race N'Dama 6407000; sheeps and goats 459400. These species composed of local breeds are very hardy and adapted to their environment. Their diet is based on rich and varied natural pastures of about 70000 km^2 with nearly 350 forage species. The breeding of pigs has 500000 semi-improved breeds. The poultry herd is estimated at 28400000 poultry of local varieties on traditional farms and 1500000 hens of improved strains in semi-intensive poultry farms. Thus, more than 10 million tons of waste (dung, slurry, dung, droppings, etc.) are produced each year, but are very little valued as fertilizer in most parts of the country [8].

Compared to these data, in forest areas, for example in Macenta, Gueckedou, N'Zerekore, Beyla, Lola, Diecke, large farms have seen their last years because of the development of mining and agricultural activities. The management of these farms currently poses many problems namely: the stray animals, waste management and litter. Hence the aim of this research is to evaluate the biogas potential of animal waste in order to establish waste recovery units for the production of thermal and electrical energy in these rural unconnected areas in Guinea.

2. Methodology

2.1 Description of the study area

The prefecture of Macenta is an administrative subdivision of the Nzérékoré region, it is located in the southeast of the Republic of Guinea 700 km from the capital Conakry. Macenta lies between latitude 8°32'37" N and longitude 9 °28'22" W with an average elevation of 609 m. It covers an area of 2724 m^2, with a population of 278456 inhabitants in 2014 of which nearly 70% of the population live in rural areas. The Macenta relief is entirely dominated by the Guinean ridge. Its climate is subequatorial characterized by the alternation of two seasons of unequal duration, the dry season (3 months) from December to February and the rainy season (9 months) from March to November with an average annual rainfall of 1085 mm . The average annual temperature hovers around 25°C, the North-East winds have an average speed of 0.6 m/s with an average humidity of 60% [9]. The prefecture of Macenta is subdivided into 14 sub-prefectures plus the urban commune, namely: Balizia, Bindikala, Bofossou, Daro, Fassankoni, kouankan, Koyamay, Macenta center, N'Zebela, Orémai, Panziazou, Semgbedou, Sérédou, Vasérédou , Watanka [9].

2.2 Methods

The methodology for assessing the biogas potential of animal waste is based on theoretical and practical approaches. It consisted of: inventorying animal herds, evaluating the daily production of waste by animal, characterizing the samples of each type of waste and finally evaluating the biogas potential of the types of waste. Samples of this waste (cow dung, pig manure and hen dung) were analyzed in the Microbiology laboratory of the National Office of Quality Control (ONCQ) of Conakry. The gravimetric method was used to determine the density (Mv), the moisture content (H), the Dry Matter (DM) and Volatile Matter (VM). The volumetric method made it possible to determine the Organic Carbon (CO) according to the French standard NF U 44-161 [10] and the Total Nitrogen (NT) which was determined by the Kjeldahl method [11]. The pH was determined by the indicator strips.

The census of livestock (cattle, pigs and poultry), took place from September 15 to October 10, 2017, with the collaboration of the Prefectural Directorate of Livestock and Animal Productions of Macenta. The method for assessing daily waste production per animal consists of making different daily weights for each type of waste during the investigation period.

The daily evaluation of cow dung per animal took place on a cattle farm in Vasseredou, out of a population of 30 cattle, including 17 females, 5 males and 8 calves with a variation of age from 4 months to 6 years, the average weights of these animals range from 50 to 250 kg. These animals are fed on natural pastures during the day and are housed in pens in the evening.

The daily assessment of pig slurry was conducted in two (2) family farms, depending on the type of farm (semi-improved and local). The local type in one of the Orémai farms out of 20 pigs including 15 sows and 5 boars, ages ranging from 2 months to 3 years and average weight 20 to 80 kg. For the semi-improved type on a farm in the Urban Commune of Macenta on a population of 148 pigs including 18 pigs, 45 sows, 85 boars, ranging in age from 1 month to 2 years with weights ranging from 10 to 150 kg . These animals are fed mainly on palm kernels, rice waste, maize, cassava, banana, potato leaves, fish scales and cooking salt.

The daily assessment of the hen dung was carried out on a family farm of laying hens in the village of Bokoni. It covered a population of (N_p = 500) laying hens 6 months old with an average weight of 1.5 kg. They are raised on sawdust, their diet is mainly composed of corn, rice bran and fishmeal. The method consisted in weighing the amount of sawdust (M_i = 1200 kg) used in the hen house for a period (t = 120 days). After this period we re-weigh the sawdust mixed with the droppings to find (M_f = 1800 kg). Thus, the average daily quantity of droppings [$Q_{jmf}(m^3/d)$] of each individual is calculated by the following equation (1).

$$Q_{jmf} = (M_f - M_i) / N_p.t \tag{1}$$

The daily biogas potential of the waste of each livestock type is calculated by equation (2).

$$P_{jbiog} = N_a \times Q_{jd} \times (\%MS) \times (\%MV / MS) \times (\%Biog/MV) \tag{2}$$

Where:

P_{jbiog}: Daily biogas potential of waste in (m^3 per day); N_a: Number of animals of each type of livestock; Q_{jd}: Daily quantity of waste produced per animal in (kg per day); (%MS): Proportion of dry matter contained in the waste; (%MV/MS): Proportion of volatile matter contained in the dry matter; (%Biog/MV): Portion of biogas contained in the volatile matter.

3. Results and discussions

The results of the census of flocks by locality of Macenta are given in Table 1.

Table 1: Number of animals per flock and per location

N°	Locality	Animal populations			
		Cow	Pigs semi-improved	Pigs local	Hens
1	Balizia	30	247	65	0
2	Bindikala	700	551	124	0
3	Bofossou	14	495	215	0
4	Daro	13	2 875	625	0
5	Fassankony	30	100	50	0
6	Kouankan	3 242	1 575	425	1 080
7	Koyamah	20	483	78	0
8	C.U. Macenta	22	1 987	1 540	5 253
9	N'Zébéla	20	506	128	0
10	Orémai	10	540	168	8 100
11	Panziazou	28	445	105	4 272
12	Sengbédou	35	295	85	400
13	Sérédou	25	1 920	1 280	900
14	Vassérédou	8 622	0	36	0
15	Watanka	575	349	126	0
Total		13386	12368	5050	20005

Table 1 shows that cattle breeding is practiced in the fifteen (15) localities of Macenta with a maximum number of people in Vassérédou (8622) which corresponds to 64.41% of the total cattle population (13 386). Semi-improved pig rearing is practiced in the fourteen (14) locations out of fifteen (15) with a total population of (12368).

Local hog breeding is practiced in the fifteen (15) localities with a population of (5050). Thus, pig farming has a total workforce of (17418). In the end the breeding of laying hens is practiced in six (6) localities out of the fifteen (15) with a total of 20005 hens. The results of the average values of daily waste by type of livestock and animal are given in Table 2.

Table 2: Daily averages of the quantities produced per animal of each herd

N°	Type of livestock	Daily quantity of waste produced (kg per day)
1	Cow dung	4,23
2	Slurry of local pigs	2,41
3	Slurry of semi-improved pigs	2,21
4	Laying hens	0,013

The average daily values of cow dung produced (4.23 kg per day) are lower but relatively close to the results of Lacour J. [5] or (4.50 kg per day), whereas the daily pig excrements (2.41 and 2.21 kg per day) are slightly higher than in the literature ie 2 kg per day [5]. For the production of chicken droppings (0.013 per day), they are also slightly higher than those of the literature [5] or (0.011 kg per day). These differences between our results and those of other authors are due to the mode of breeding, the animal behavior, the diet and the potentialities of the physical environment. Values for the characterization of physicochemical parameters of animal waste from Macenta are given in Table 3.

Table 3: Physicochemical Parameters of Animal Wastes

Type of livestock	H(%)	MS(%)	MV(%)	Mv(kg/m3)	C(%)	N(%)	C/N
Cow dung	82	22	52	593,75	30,28	1,66	18,27
Slurry of local pigs	72	24	31	623,44	18,06	1,52	11,88
Slurry of semi-improved pigs	68	21	28	623,44	16,24	1,44	11,26
Laying hens	62	34	62	257,23	35,97	1,98	18,18

Table 3 shows that:

- The dry matter (DM) content of cow dung (22%) is higher than that of the literature, ie 15%. For pig manure on semi-improved and local farms, respectively: 24% and 21%. These values are very close to that of the literature (20%) [5]. The proportion of MS in chicken manure is 34%, it is relatively close to 30% [4].
- The proportion of volatile matter in the dry matter (MV/MS) cow dung is 52%, it remains very close to 55% [7]. The proportions of (MV/MS) in pig manure in semi-improved and local breeding are respectively 31% and 28%. These values are relatively close to 35% [4]. The proportion of (MV / MS) in chicken manure is 62%, very close to 60% [5].
- The carbon content of waste (dung, slurry, dung) is respectively 30.28%; 18.06% and 35.97%. These values are suitable for the growth and growth of microorganisms in anaerobic digestion [7].
- Carbon-Nitrogen (C/N) ratios of animal waste from Macenta are 18.27; 11.88; 11.26 and 18.18. These results are close to the range of optimal values (20 to 30) for the optimal production of biogas [7].
- The moisture content of waste (dung, slurry, dung) is respectively: 82%; 62%; 72% and 68%). These results are included in the range favorable to anaerobic digestion, ie 60% to 80% [2]. Figure 1 shows the physicochemical parameters of waste.

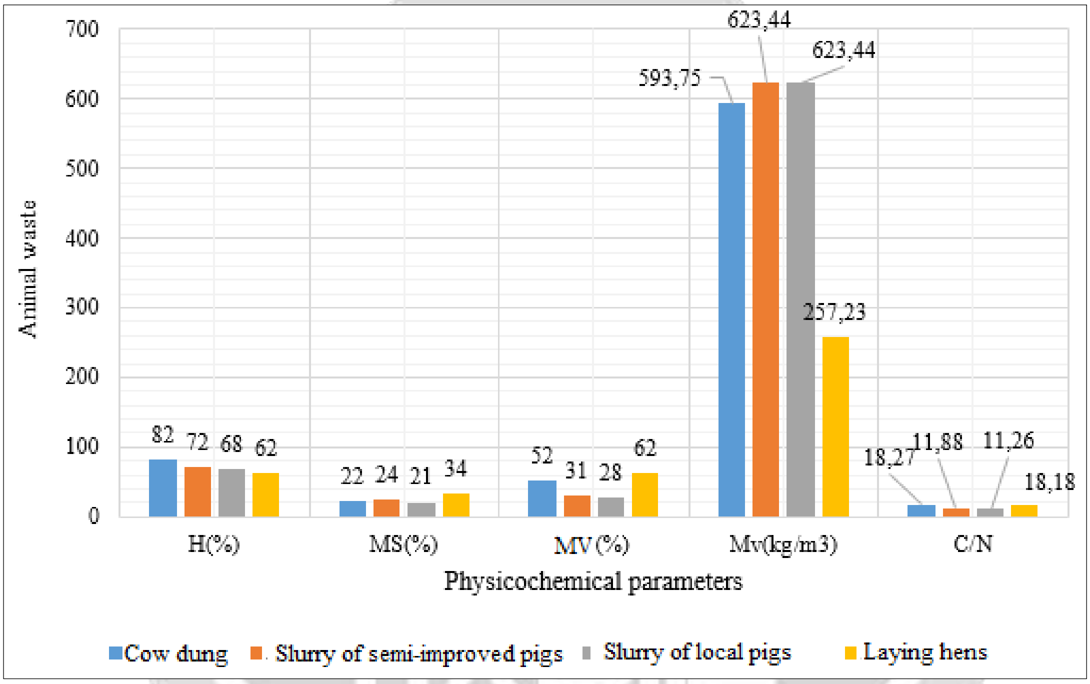


Figure 3: Physicochemical parameters of waste

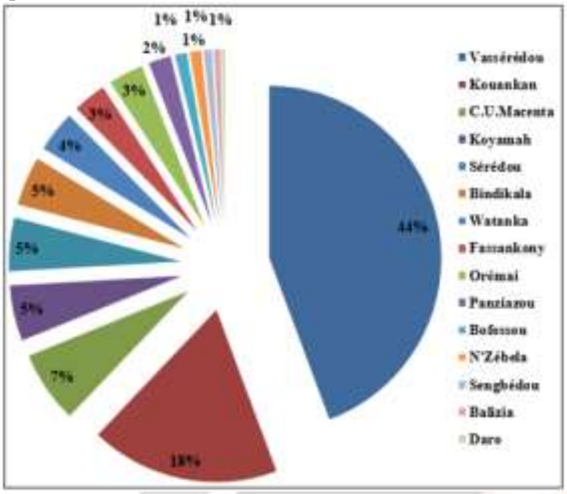
The diagram in Figure 1 shows that the physicochemical parameters of the manure of the different types of herds are different, this is due to their diets. The daily biogas potentials of animal waste (cow dung, pig manure and hen dung) in Macenta localities are determined on the basis of physicochemical and biological characteristics. The results obtained are given in Table 4.

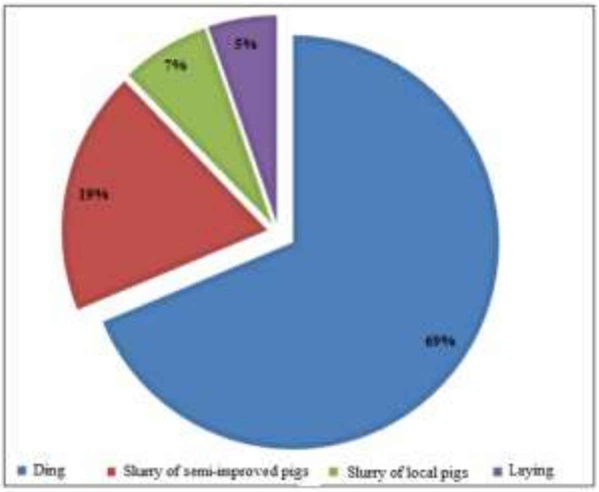
Tables 4: Biogas potential of cow dung, hog manure and hen dung waste

N°	Locality	Cow dung	Slurry pigs semi-improved	Slurry pigs local	Foie hens	TOTAL (m3/d)
		Biogas (m^3 per day)	Biogas (m^3 per day)	Biogas (m^3 per day)	Biogas (m^3 per day)	
1	Balizia	13,815	34,155	7,746	0,000	55,717
2	Bindikala	322,359	76,193	14,778	0,000	413,330
3	Bofossou	6,447	68,449	25,623	0,000	100,519
4	C.U.Macenta	10,131	397,557	74,485	126,191	608,364
5	Daro	5,987	13,828	5,959	0,000	25,774
6	Fassankony	13,815	217,792	50,650	0,000	282,257
7	Kouankan	1492,983	66,790	9,296	25,944	1595,013
8	Koyamah	9,210	274,764	183,532	0,000	467,505
9	N'Zébela	9,210	69,970	15,255	0,000	94,435
10	Orémai	4,605	74,672	20,022	194,584	293,882

11	Panziazou	12,894	61,535	12,514	102,625	189,568
12	Sengbédou	16,118	40,793	10,130	2,098	69,139
13	Sérédou	11,513	265,499	152,546	21,620	451,178
14	Vassérédou	3970,543	0,000	4,290	0,000	3974,833
15	Watanka	264,795	48,260	35,038	0,000	348,093
	TOTAL	**6164,427**	**1710,254**	**621,863**	**473,063**	**8969,606**

Figures 2 and 3 show the distribution diagrams of the biogas potential of the animal waste by localities and by type of livestock.





The results obtained show that the daily biogas potential of animal waste from Macenta is 8969.606 m^3 per day, ie an annual production of about 3273906.19 m^3 of biogas. This energy could cover some of the energetic needs (cooking, lighting, water pumping, cold production) of the different localities of the area. The distribution of this potential by localities and by livestock is unequal, ie (44%) for Vasseredou, followed by Kouankan (18%), the Urban Commune of Macenta (7%) each and the others have values that vary from 5% to 1%. From the point of view of distribution by type of animal waste we have: cow dung (69%), semi-improved and local hog slurry respectively (19%) and (7%) and finally the chickens (5%).

4. Conclusion

This research shows that a significant part of the energy needs of the rural population of Macenta prefecture can be met by a valuation of animal waste, especially with the rapid development of livestock in the last ten years (the multiplication of farms). In order to optimize this energy and agricultural potential of this animal waste, it is essential to organize regular surveys of the different types of flocks for the precise assessment of the number of animals. The development of this energy potential of animal waste will result in the installation of appropriate digesters, energy production devices and the marketing of biogas-consuming equipment at the local level.

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