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Study of the Evaluation of the Biogas Potential of Waste from the Agricultural Farm of Denken in Boke, Republic of Guinea

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Abstract: In rural and suburban areas of Guinea, waste and organic residues generated by agricultural and agro-industrial activities are traditionally valued in situ in animal feed as provender, in soil fertilization and for energy purposes as fuel. This work puts a cent on the opportunity of a better recovery of this agricultural waste by methanization. The adopted method consists in: quantifying the biodegradable waste of the farm; determine the physicochemical characteristics of these various methanizable wastes and assess the biogas potential of these wastes. The main results obtained are: The average annual quantities of waste produced on the farm are: cow dung 400 tons, stubble or rice stalks 40000 tons and rice husks 2700 tons; physicochemical parameters: (*i*) cow dung: Humidity (64%), Dry Matter (36%), Organic Matter (65%), density (203kg/m^3), Carbon content 38% and carbon content Nitrogen (1.71%), (*ii*) rice stubble: Moisture (27%), Dry Matter (73%), Organic Matter (51%), Density (193 kg/m^3), Carbon (30%) and Nitrogen (1.95%); (*iii*) rice husk, Moisture (16%), Dry Matter (84%), Organic Matter (36%), Density (163 kg/m^3), Carbon (21%) and Nitrogen (1.46%); cumulative production of biogas in co-digestion: cow dung (0.066 m^3), rice stubble (0.039 m^3) and rice husks (0.042 m^3); the cumulative production of biogas in co-digestion: rice stubble with rice husks (0.0437m^3), cow dung with rice husks (0.0482 m^3), cow dung with rice husks (0.0711 m^3) and cow dung cow with rice stubble and rice husks (0.0808 m^3); the pH varied from 7 to 8.5 in cow dung, rice stubble and codigestion substrates and from 6 to 8 in rice husk, respectively. During the 45 days of the process, the digestion temperature in the different digesters varied from 24 to 31°C with averages varying from 26°C to 28°C. The results of this study show the importance of the diversification of organic matter for the optimal production of biogas, which also makes it possible to locally mitigate methane emissions from livestock and crops in Agricultural farms.

Keywords: Evaluation, Valorization, Waste, Agro-pastoral, Digester, Biogas

1. Introduction

Population growth, changes in lifestyles and energy consumption have led to an intensification of agricultural production systems and industrial activities resulting in the emission of large quantities of organic waste products. In the presence of an inadequate or deficient management system, these organic waste products can cause harm to the environment and human health [1]. Anaerobic digestion and biogas production technologies from organic waste products are unique compared to other renewable energy sources in that they allow Guinea in particular to benefit from them. The production of clean energy and decentralized electricity contributes as part of an energy mix to reduce the negative impact of the use of wood and fossil fuels as fuels. Recycling digestate on cultivated soils also contributes to improved agricultural performance and food security [2].

In rural and peri-urban areas of Guinea, organic waste and residues generated mainly by agricultural and agro-industrial activities are traditionally valued in situ in animal feed as feed, in soil fertilization as an organic amendment and/or for energy purposes as fuels. At the same time, at city level, organic waste is mostly disposed of without any form of segregation in uncontrolled landfills [3]. In Guinea, nearly 70% of the population is rural and lives mainly on agricultural and livestock products. In addition, less than 15% of this population is connected to the country's electricity network, which has the negative consequence of deforestation through the use of wood as a source of energy [4].

However, the agricultural herd in Guinea is estimated at 6.7 million hectares of which only 1.6 million hectares are cultivated, of which 750000 hectares are devoted to rice cultivation. Rice is the keystone of the food system of Guineans, who are among the largest consumers of rice in Africa. National consumption varies according to natural regions [1]. In 2017, the national breeding herd numbered 6407000 mainly N'Dama cattle; sheep and goats 459400. Pigs have 500000 heads of semi-improved breeds. The poultry flock is estimated at 28400000 poultry of local varieties in traditional farms and 1500000 hens of improved strains in semi-intensive poultry farms. Thus, more than 150 million tonnes of agricultural waste (stubble, bales of droppings, slurry, manure, pig dung, etc.) are produced each year, but are very little used in the energy sector [5].

The assessment and valuation of the energy potential of agricultural inputs would make it possible to consider, in rural areas not connected to public and private electricity grids, the installation of digesters for the production of electrical and thermal energy. Also, the production of energy from organic matter of various origins (plant matter, animal excreta, sludge from sewage treatment plants, household waste, etc.) by means of anaerobic fermentation processes in suitable digesters would allow better management. Waste preservation of the environment and sustainable development of rural areas, as well as diversification of the energy supply (alternative energies) adapted to the local context and within the reach of the said population [6, 7].

The Denken farm in Boke in the maritime region is an agro-pastoral farm (of agriculture and breeding) par excellence, the agricultural waste and animal excreta produced on this farm are valued only as fertilizer but almost not used in the energy sector (biogas production). Hence the objective of this research, which concerns the evaluation of the biogas potential of waste from the Denken agricultural farm in Boke (Republic of Guinea).

2. Materials and Methods

2.1. Presentation of the Study Area

This research took place in the prefecture of Boke in Guinea Maritime, at a distance of 300 km from Conakry. It is between 10°56' and 10°60' of the North latitude and between 14°17' and 14°20' of the West longitude with an average altitude of 800 m. Boke prefecture covers an area of 31186 km^2 with a population of 1081445 inhabitants. The Climate is characterized by the alternation of two seasons, the dry season from November to April and the rainy season from May to October, precipitation varies between 1700 mm and 2000 mm, with an average annual temperature of 25°C [8].

The Denken farm has an area of 405 ha, in which four (4) rice varieties (Djoukeme, Ck-801, Mohameya and p6) are cultivated, with an average annual production of 2000 tonnes of paddy rice. In the cattle yard of the farm, 250 head of oxen are raised on the farm, the cow dung produced is currently used for organic fertilizer purposes.

2.2. Materials

Several materials were used during this work, namely: i) For the evaluation of the potential of methanizable waste (the questionnaire guide, the decameter, and the scale); ii) for the physicochemical characterization of the substrates (drying ovens, calcination ovens, analytical balance, stirrer, tongs, test tube, beaker and cylindrical vessel); iii) for the experimental production of biogas (temperature sensors, a professional balance, a pH meter, graduated vessels, valves, flexible pipes, etc.).

2.3. Methods

The methodology adopted is subdivided into three stages: i) the evaluation of the quantity of methanizable waste from the farm, ii) the physicochemical characterization of these substrates and iii) the experimental evaluation of waste biogas in mono and co-digestion. The quantification of the waste was carried out in five (5) different places of the farm field. We proceeded to count the rice stalks of several feet in order to know the average number of feet and stalks per feet per square meter.

The amount of husks (bran) is obtained by feeding one tonne of paddy rice into the piling machines for one hour. Then we reweighed the final quantity (grains of rice), so the difference of the two weighings represents the quantity of husks. The average daily production of cow dung on the farm is determined by weighing the amount of dung produced per cow for two months at different seasons of the year [4].

The characterization of the physicochemical parameters (density, relative humidity rate, dry matter rate, organic matter rate, mineral matter rate, carbon rate and nitrogen rate) of samples of farm waste (cow dung, rice stubble and rice husks) was carried out by the gravimetric method and the volumetric method [9, 10].

The experimental evaluation of the biogas potential was carried out on 1 kg of each type of substrate (dung, stubble and rice husks) in mono-digestion, then in co-digestion (cow dung + rice stubble, cow dung + husks of rice, rice stubble + rice husks and cow dung + rice stubble + rice husks, at 50% each, i.e. 500g of each type of substrate). We simultaneously used seven (7) 4.5 liter plastic bottles as digesters and fourteen (14) others of the same volume. Three (3) bottles are used for each substrate, the first of which is considered as a fermenter, the second as a gasometer filled with water and the last vacuum to collect the water which is emptied from the gasometer under the pressure of the produced biogas. The fermenters were each loaded with one kilogram (1 kg) of substrate with a dilution of 2 liters of water. The devices of the experiment are shown in Figure 1.

Figure 1. *Experimental digesters.*

3. Results and Discussions

3.1. Potential for Methanizable Farm Waste

The annual average potentials of the farm's various methanizable wastes are shown in Figure 2.

The average annual quantities of waste produced on the farm are: cow dung 400 tonnes, stubble or rice stalks 40000 tonnes and rice husks 27000 tonnes. These values represent an estimate that depends on annual agricultural yields. The energy recovery of this waste would make it possible to locally produce clean energy and quality fertilizers on the farm. This recovery also makes it possible to locally reduce nuisances and greenhouse gas emissions (CH_4, CO_2 and NO_2) due to the livestock sector.

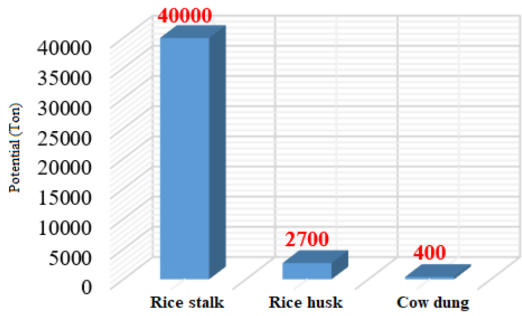

Figure 2. *Average annual potential of methanizable waste from the farm.*

Table 1. *Physico-chemical parameters of farm substrates.*

Types of substrates	H (%)	DM (%)	MO (%)	D (m^3/kg)	C (%)	N (%)	C/N
Cow dung	64	36	65	203	38	1,71	22
Rice stubble	27	73	51	193	30	1,95	21
Rice husk	16	84	36	163	21	1,46	16

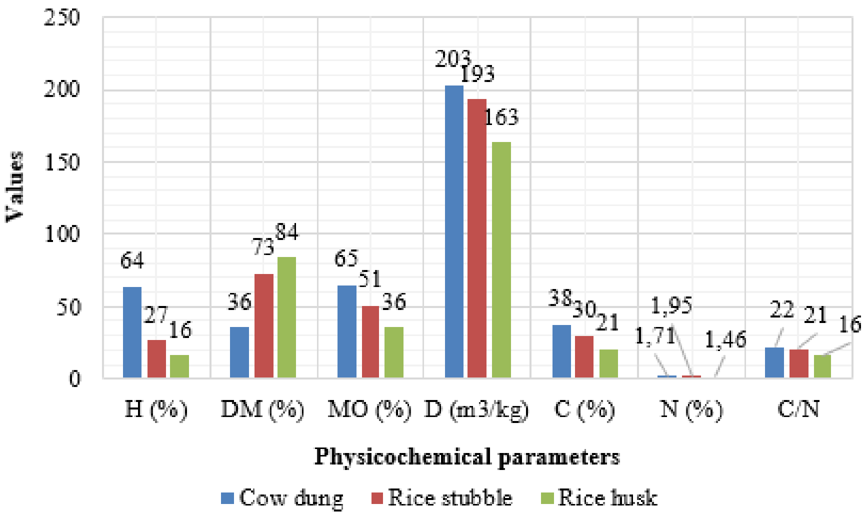

Figure 3. *Characterization of the physicochemical parameters of the substrates.*

3.2. Physicochemical Characterization of Substrates

The results of the characterization of the physicochemical parameters of the substrates are illustrated in Table 1 and in Figure 3.

The diagrams in Figure 3 show that cow dung and rice stubble are rich in carbon (38%, 30%) and rice husk is less rich in carbon, ie 21%. These three inputs have a respective organic nitrogen rate of 1.46%, 1.95% and 1.71% with respective

Carbon and Nitrogen (C/N) ratios: cow dung (22), rice stubble (21) and rice husk (16). The dry matter (DM) rates of the samples are: cow dung (36%), stubble or rice stalks (73%) and rice husk or bran (84%). The organic matter (OM) rates are: cow dung (65%), rice husk (36%) and rice stubble (51%). The results obtained show that the farm waste co-digestion system allows optimal production of biogas [11]. These results are consistent with those of some researchers [12].

3.3. Potential of Waste Biogas

The results of the experimental evaluation of the biogas potential of farm waste in mono-digestion and co-digestion are illustrated as follows.

3.3.1. Biogas Production in Mono-digestion

The cumulative production of biogas in mono-digestion of farm waste is presented on the curves in Figure 4.

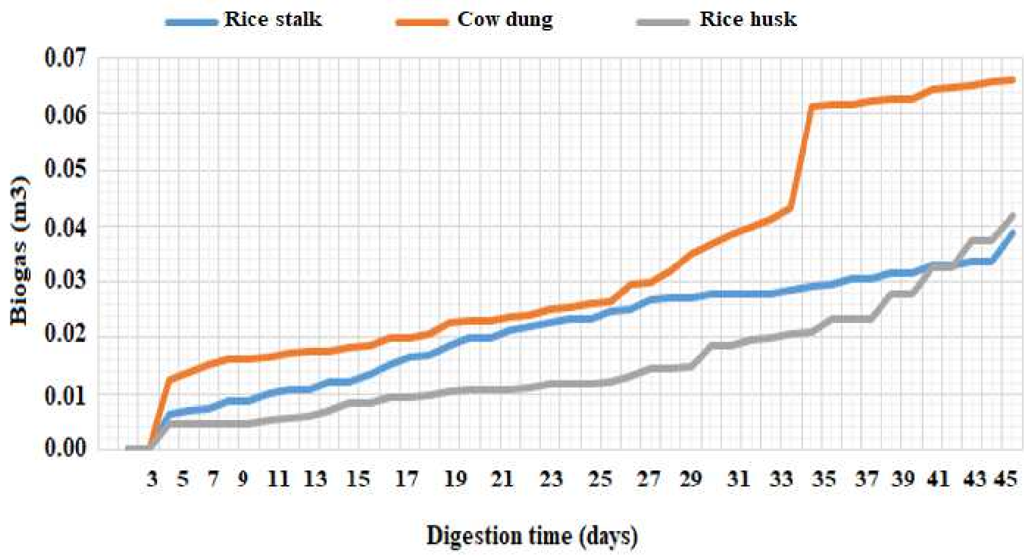

Figure 4. *Cumulative production of biogas in mono-digestion.*

The production of biogas began on the third day after loading the digesters and lasted 45 days in an environment of average temperature varying between 26 and 30°C. The cumulative productions were respectively: cow dung (0.066 m^3), rice stubble (0.039 m^3) and rice husks (0.042 m^3). The cumulative production curve of cow dung biogas shows a rapid increase in biogas production between the 33rd and the 34th day, this rapid increase is due to a sudden change in certain parameters (temperature and pH) which is very favorable methanogenic microorganisms for the production of biogas. This process remains similar to the research work of our previous works [13].

3.3.2. Production of Biogas in Co-digestion

The cumulative production of biogas in co-digestion of farm waste is presented on the curves in Figure 5.

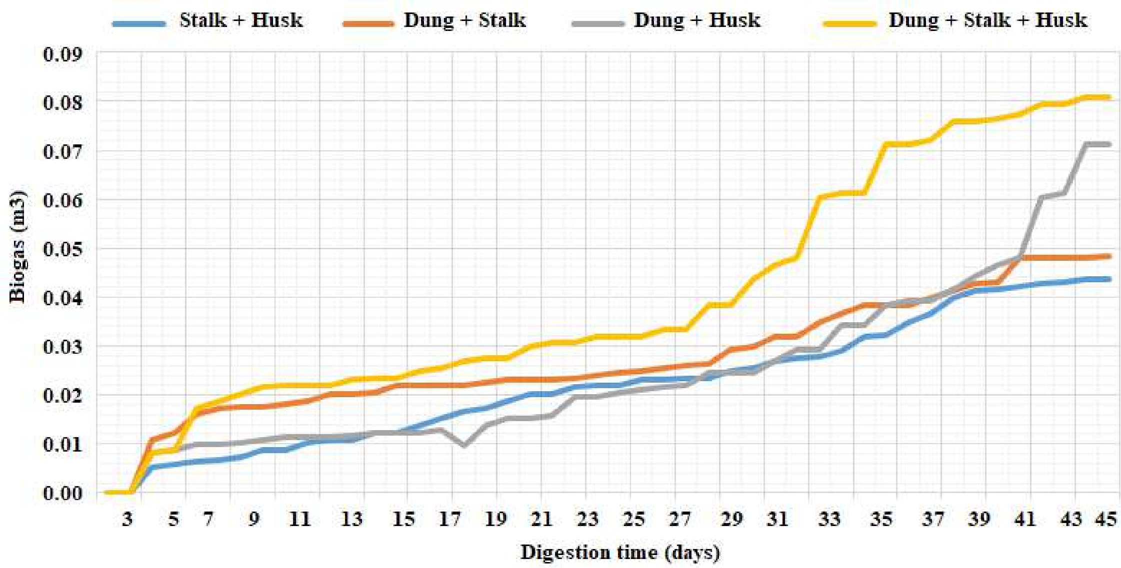

Figure 5. *Cumulative production of biogas in codigestion.*

During the 45 days of anaerobic digestion, the cumulative production of biogas recorded by the various substrates in codigestion are as follows: rice stubble with rice husks ($0.0437 m^3$), cow dung with rice stubble ($0.0482 m^3$), Cow dung with rice husks ($0.0711 m^3$) and cow dung with rice stubble and rice husks ($0.0808 m^3$). The results show that, the codigestion of the three types of substrates produces more biogas than the others, followed respectively by cow dung with rice husks, cow dung with rice stubble and rice stubble with rice husks. This proves that the codigestion of biodegradable agricultural waste with cow dung optimizes the production of biogas compared to mono-digestion [13, 14]. During the process, the temperature in the digester of the substrates in the different digesters varied from 24°C to 31°C with averages varying from 26°C to 28°C. These values are relatively equal to those found in the work of T. Ibrahima and al., B. Ibrahima and al., [15, 16]. Which corresponds to the mesophilic mode of digestion.

3.3.3. Evolution of Temperature and pH

The variation in pH in the four fermenters during production is given in Figure 6.

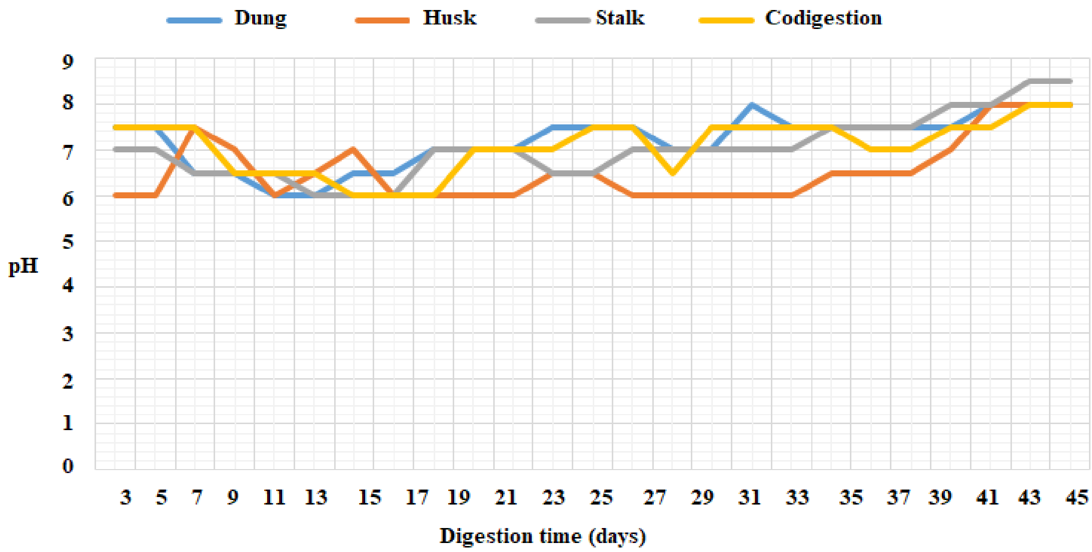

Figure 6. *Evolution of the pH during the experiment.*

The curves in Figure 6 show the evolution of the pH in the fermenters. It varied from 7 to 8.5 in cow dung, in rice stubble and in codigestion substrates, and from 6 to 8 in rice husk, respectively. These values remain very favorable to the development of microorganisms for anaerobic digestion. During the process, the evolution of the pH in the different substrates obeyed the following three (3) phases: acidification, alkalization and stabilization [17, 18].

4. Conclusion

The originality of the objectives of this research is the evaluation and valuation of the energy potential of methanizable waste from agro-pastoral farms through the production of biogas. Knowledge of the physicochemical parameters of this waste makes it possible to optimize their biogas potential. The energy and digestates from this farm waste will improve energy problems (lighting, heat and cooking) and organic fertilizers for the improvement of the farm's cultivable soils. This work also allows local limitation of methane emissions due to livestock and crops on the farm. Analysis of the results of this work puts into perspective the construction and operation of an industrial digester with an average capacity of 50 m³ in order to ensure efficient management of all methanizable waste on the farm.

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