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Realization and Experimentation of a Digester from a Fut at Julius Nyerere University af Kankan, Guinea

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Abstract: *Digesters are anaerobic bioreactors generally made up of closed tanks, airtight and thermally insulated from the outside in which different microorganisms chemically and biologically degrade organic waste and effluents to produce biogas. This research led to the realization and testing of a digester from a metal drum at Julius Nyéréré University in Kankan. The digester was loaded on January 10, 2020 with cow dung diluted with water. After 30 days of digestion, the produced biogas was tested for fuel by boiling water and roasting the eggs. During the digestion process, the variation in temperature and pressure revealed that it is necessary to thermally insulate the tank (digester) or to place it in an isothermal chamber favorable to the development of metagenesis bacteria. Monitoring of the change in pH showed three phases (acidification, alkanization and stabilization).*

Keywords: Realization, Digester, Drum, Volume, Cow dung, Biogas

1. INTRODUCTION

One of the fundamental priorities of countries around the world is the management and protection of the environment, ecosystems and biodiversity. Scientific and political debates on these subjects are becoming more and more numerous and varied [1].

Despite these scientific and political efforts, the population of rural areas in poor countries remains heavily dependent on biomass to meet their daily energy needs. This dependence is caused by a low rate of energy supply to its populations and this constitutes a major handicap for their socio-economic development. This very great dependence of these populations on biomass has many negative effects on both the local environment (deforestation, reduction in soil fertility, etc.) and the global environment (climate change) [2]. The negative impacts on living conditions, mainly of women and children, must also be considered, linked in particular to the collection of biomass and the smoke released by the combustion of these collected biomasses which even exposes these women and children to respiratory and eye diseases.

However, the exploitation of natural resources as a source of energy should be carried out under strict control by the authorities, which would not only ensure that energy needs are met, but also conserve resources for future generations. Unfortunately, the situation is far from being the case in Guinea and particularly in Kankan in Upper Guinea. This situation could continue in the sense that it is again for no one that the energy problem is acute at all levels in Guinea. To meet their daily energy needs, people generally resort to traditional energy resources such as firewood, charcoal, dry manure, agricultural residues, etc. However, collecting traditional fuels and producing energy not only depletes natural resources, but also degrades the country's ecosystems and environment [3].

Biogas digesters are currently of major interest in the protection of our environment, our ecosystems, our fauna and flora biodiversity. They make it possible to considerably reduce: the quantities of waste to be incinerated, the volume of smoke in large cities, the quantities of waste to be stored, odor nuisance in our large cities, pathogens and diseases linked to these pathogens in our environment.
In Guinea, research on the construction of biodigesters began in the years 1977 and 1980 with the construction of experimental digesters of the Indian type at the Faculty of Agronomy of Foulaya in Kindia [4].
In general, the biomass potential (agricultural, agro-industrial residues, domestic waste, plants and animals) represents 80% of the country's total energy potential. Livestock is the second largest activity in rural areas after agriculture. The recovery of this animal waste could be considered as an economic and ecological solution through energy autonomy and sustainable agricultural development of rural areas characterized by a high animal density, most often posing difficulties within farms [5].

On the basis of these findings and in order to considerably reduce the exploitation of natural resources and its harmful effects of our environment, it seems important to us to undertake the implementation of a sustainable energy policy. This would have the advantage of not only improving the modes of production and use of renewable energies but also of satisfying the various energy needs of the populations in a sustainable manner. Achieving this objective necessarily involves making the most of renewable energy resources including biomass and the construction of biogas digesters. Hence the merits of this study: Realization and experimentation of a digester from a metal drum at Julius Nyéréré University in Kankan.

2. MATERIAL AND METHOD

2.1 Material

2.1.1 Presentation of the study area. The Urban Commune of Kankan is located 680 km from Conakry at an altitude of 377 m. It is bounded by the Rural Communes of Balandou in the East, Gbérédou Baranama in the West, Karifamoriah in the North and Tintioulen in the South. The urban commune of Kankan is made up of 27 neighborhoods, it covers an area of 250 km2, with a population of 472,112 inhabitants according to the 2014 census. This population is mainly made up of Malinkés.

The city of Kankan is part of the Upper Guinea region, it is located on the Milo River, one of the tributaries of the Niger River. Kankan is by its population the second city of the Republic of Guinea after the capital Conakry, and the largest in terms of surface. Almost all of these households use either fuelwood or charcoal, or both at the same time, or dry manure to meet a large part of the energy needs. It is a population which is mainly composed of breeders, farmers, traders, tradesmen including artisans and civil servants [6].

This work was carried out at Julius Nyerere University in Kankan. It is located in downtown Kankan, in the Kabada district. It covers an area of 4 ha. The device was installed within the walls of the said University, between Block A and the Rectorate. This is for environmental reasons (access, ventilation, sunshine, availability of water, etc.).

2.1.2 Equipment. The working materials consist of equipment for producing the device (digester) and its experimentation.

Device production equipment. A 200 liter metal drum, a car tire inner tube, a reducer, a mamelo, two butterfly valves, a chrome sleeve, a copper tee, two pipes, screw connectors, washers, a roll of white tape , two screwdrivers, four 20-liter buckets, two shovels, soap, three pairs of gloves and a funnel were used.

Equipment for experimenting and making the device. An automatic balance, two thermometers, a hygrometer, a manometer and a pH meter.

2.2 METHOD

The methodology of this study focused on two stages, the realization of the digester and its experimentation.

2.2.1 Construction of the digester. The small opening of the barrel was hermetically sealed, the large one was used as a gas outlet. A T-pipe with two valves was installed there for the recovery of gas in the air chamber and towards the stove. As the digester is a metal barrel with a volume of 200 liters and a diameter of 57 cm, the other geometric parameters of the prototype are calculated as follows [7].

- The total height of the digester (barrel) is: $H_{td} = \frac{4.V_t}{\pi.D^2}$
- The height occupied by the cow dung (digestion part) is: Hpd =2/3 Ht
- The height reserved for the biogas (gasometer part) in the drum is: Hg = Htd - Hos
- The volume of the barrel used for fermentation (digestion part) is: $V_{pd} = \frac{\pi.D^2.H_{pd}}{4}$
- The volume of the gasometer part of the digester is: $V_{pg} = \frac{\pi.D^2.H_{pg}}{4}$

2.2.2 Experimentation with the device. The interior and exterior of the drum have been thoroughly cleaned to remove all traces of petrochemicals, which interfere with the growth of methanogen bacteria. The experiment involved 68 kg of cow dung collected at the Kankan slaughterhouse. This quantity of dung was dissolved in the proportions of 5 liters of water for 4 kg of dung, ie a total quantity of water of 85 liters.

The car inner tube was used for the storage of produced gas. A reducer, a mamelo, two butterfly valves, a chrome sleeve, a copper tee, two pipes were used for the various connections. A gas stove was used for cooking from the produced biogas. Two pipes of the same diameter were used for the connection to the keg and the stove. The automatic scale was used for weighing cow dung, two thermometers to record the temperature inside the barrel (digester) and the temperature of the ambient environment, a hygrometer for measuring humidity, the pressure gauge for pressure measurement and pH meter for evaluating the change in pH during the digestion process.

According to some authors, it is established that 1 kg of cow dung produces between 0.023 and 0.040 m3 of biogas per day. Thus, the theoretical minimum volume of biogas produced (Vbp) per day is determined by the formula $V^{bp} = m_b \times 0.023$ [7].

The energy potential of biogas is a function of its methane content and its Lower Calorific Value (NCV). The PCI of methane is 9.94 kWh / Nm3 or 35784 kJ / Nm3. Also, 1m3 of 50% methane biogas is equivalent to an average of 4.58 kWh of electricity, or 16,488 kJ. The temperature of the biogas combustion flame depends on its methane content, it is between 800 ° C and 1100 ° C [4].

The daily energy potential of the produced biogas is determined by the following relation [2].

$$E_{bio} = Bp \times \%CH \times PCI_{CH4}$$

Or : E_{bio} : Daily energy production from biogas (kJ/d) ; $\%CH_4 \approx 0{,}5$: Methane content in the biogas ;
$PCI_{CH4} = 9{,}94 kW/Nm^3$: Lower Calorific Value of methane (kJ/m^3).

The stages of making and testing the device are illustrated by the photos in Figure 2.1.

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a) Fixing the air chamber

b) Collecting cow dung la bouse de vache

c) Loading the digester

d) Loaded digester




e) Biogas production

f) Pressure and temperature measurement

g) Biogas combustion

Fig.1: Stages of implementation and testing of the device

3. RESULTS AND DISCUSSIONS

3.1 Results

The various results obtained during this study relate to: the determination of the geometrical parameters of the digester produced, the load of the digester with substrate, the estimation of the gross quantity of biogas produced, the evaluation of its energy potential. The evolution of temperature, pH and pressure were followed during the process.

3.1.1 Geometric parameters of the digester. The geometric parameters of the device are as follows:

- The volume of the metal drum being 200 liters and 57 cm in diameter.
- The total height of the digester (barrel) is Htf = 78 cm.
- The height occupied by the substrates (cow dung) is Hd = 52 cm.
- The height reserved for the biogas (gasometer part) in the barrel is Hg = 26 cm.
- The volume of the barrel used for fermentation (digestion) is then Vd = 0.132 m3 or 132 liters.
- The volume of the gasometer part of the digester is Vg = 0.066 m3 or 66 liters.

3.1.2 Digester load and daily biogas production

- The digester was loaded on January 10, 2020 with 68 kg cow dung mixed with 85 liters of water.
- After 30 days of digestion, it was estimated a minimum daily production of 1.564 m3 / d, or (1564 liters per day) of biogas.
- The daily energy potential of the biogas produced is 7.773 kWh, i.e. an electrical power of 323.87 W.

3.1.3 Evolution of pressure, temperature and pH. The digestion process lasted 30 days, from January 10 to February 8, 2020. During this period the evolution of pressure, temperature and pH was followed from 9 am to 5 pm, for 6 days (19, 23, January 27, 31, February 04 and 08, 2020). These variation curves are illustrated by figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8.

Fig. 3.1 : Variation of pressure and temperature 01/19/2020

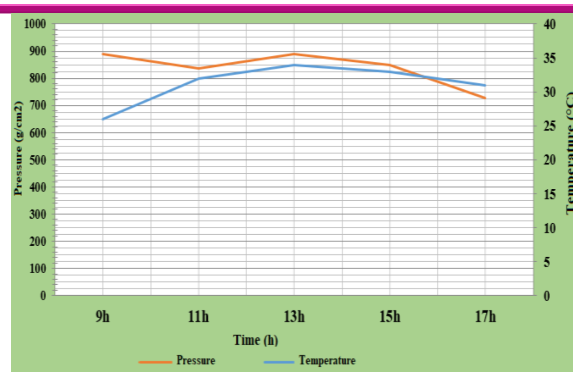

Fig. 3.2 : Variation of pressure and temperature 01/23/2020

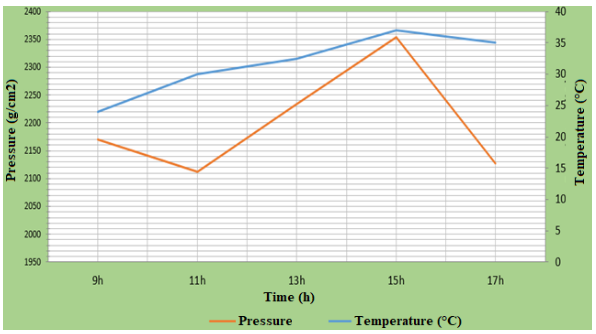

Fig. 3.3 : Variation of pressure and temperature 01/27/2020

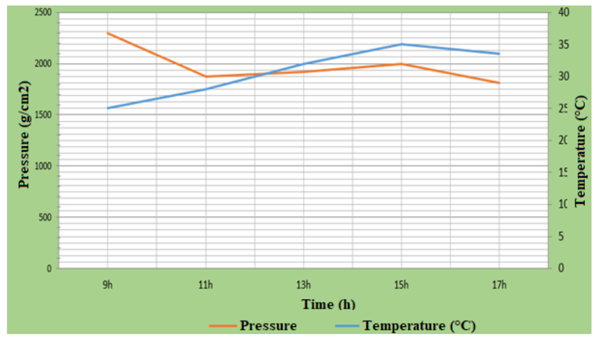

Fig. 3.4 : Variation of pressure and temperature 01/31/2020

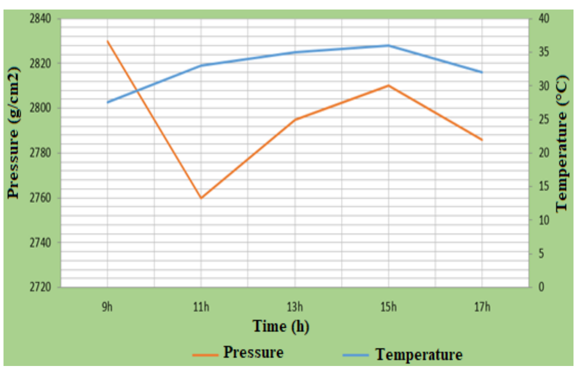

Fig. 3.5 : Variation of pressure and temperature 02/04/2020

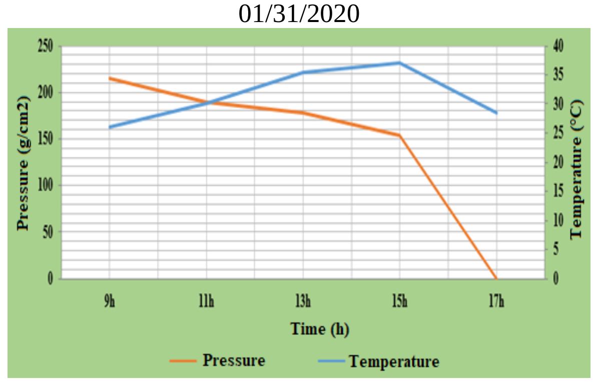

Figure 3.6 : Variation of pressure and temperature 02/08/2020

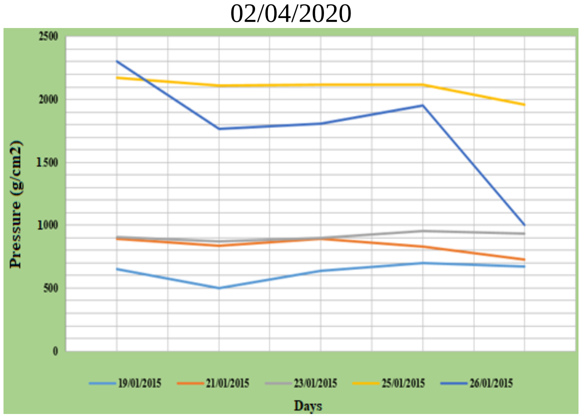

Fig. 3.7 : Evolution of the pressure for 19, 23, 27, 31/01 and 04/02/2020

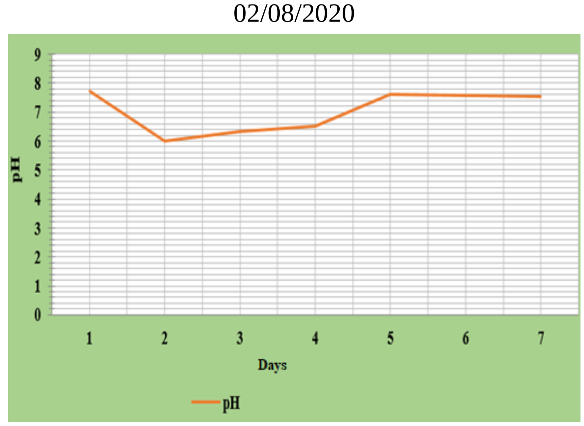

Fig. 3.8 : Variation of pH

3.2 Discussions

The results obtained during this work show that the digester carried out worked well, with a minimum daily production of biogas of 1564 liters for a quantity of substrate of 68 kg of cow dung [8, 9]. This result is consistent with the values of the literature. Thus, the use of materials as a digester would also make it possible to make a good extension of the promotion at a lower cost of the production of biogas in agro-pastoral areas. During this digestion process, certain parameters (temperature, pH and pressure) monitored daily from 9 a.m. to 5 p.m. showed the following:

After 10 days of loading the digester on 01/19/2020, the production of biogas has started. On this date from 11 a.m. to 3 p.m., we noted an increasing variation in pressure and temperature, respectively (30 to 36 ° C) and (500 to 700 g / cm2), from 3 p.m. to 5 p.m. h, the pressure and temperature dropped from 36 to 35.5 ° C and from 700 to 675 g / cm2 (Figure 3.1). This temperature range (mesophilic digestion) is always favorable to microorganisms favorable to digestion [3]. The variation in methanization parameters (temperature and pressure) have been influenced by certain climatic conditions (cloudy, clear skies), favorable or unfavorable sunshine, which causes a fluctuation in the production of biogas.

The day of January 23, 2020 was not very sunny. A slight change in temperature was recorded from 1 p.m. to 5 p.m. This situation has had an impact on the pressure of the biogas produced, the variation of which follows that of the temperature. However, it should be noted that it continued to increase (640 and 890g / cm2) at 1pm compared to the first day (figure 3.2).

The day of January 27, 2020 was very sunny with a sharp increase in temperature. We recorded a strong production of biogas (2112 to 2354g / cm2) from 11h to 15h. From 3 p.m. to 5 p.m. production decreased with the refreshment of nature. Production has increased from (2354 to 2127g / cm2). For that day, the pressure and temperature varied uniformly. They both increased and decreased (Figure 3.3). Although the weather conditions were bad, for the day of January 31, 2020, the pressure continued to increase. At 1 p.m., it was 1920g / cm2. This increase is justified by the increase in the quantity of biogas produced (figure 3.4).
The day of February 04, 2020 was a day of temperature growth from 9 a.m. to 3 p.m., favored by good weather conditions, varying from 27.5 to 36 ° C. This increase in temperature favored the growth in the pressure of the biogas from 11 a.m. to 3 p.m. It increased from 2760 to 2810 g / cm2. It can be seen that from 11 a.m. to 5 p.m., the temperature and pressure vary uniformly. They increase from 11 a.m. to 3 p.m. and decrease from 3 p.m. to 5 p.m. (figure 3.5).

On 02/08/2020, although the temperature increased from 11 a.m. to 3 p.m. (30 to 37 ° C), the pressure decreased from 189 to 154 g / cm2. It became void from 5 p.m. This decrease until canceled is due to the depletion of the substrate constituting the nutrient and energy source of the methanogenic bacterial flora responsible for the production of biogas. Thus, figure 3.7 shows that during the 30 days of digestion, the pressure in the digester generally varied in an increasing way from the first to the last day from 11 a.m. to 3 p.m. and then experienced a decrease until 5 p.m. except for a few days when the weather conditions were bad.
Monitoring the change in pH (Figure 3.8) shows the stages in the process to be :

The first ten days we observe a marked drop in pH from 7.71 to 6.00, this means that the initial cow dung is more basic. This step corresponds to the acidification phase of the substrate. From the 10th to the 15th day, the pH remained almost stable. It went from 6.00; 6.32 to 6.53. This phase is the alkalization phase. There is a slight increase in biogas production. From the 15th day, we observe a return of the pH values to 7.5 and a stabilization around this value. Note that the production of biogas is much more favorable than for the more neutral substrate. This is the phase which corresponds to the methanogenic stage. This justifies that the pH is a good indicator of the possible malfunction of a digester. The optimum value for anaerobic digestion is around neutrality (6.8 to 7.5) [10].

4. CONCLUSION

This work focused on the realization and testing of a digester from a 200-liter metal drum with discontinuous feed. It emerges from this work that this type of device has the advantage of using little water, accepts different substrates (liquid and solid), it is easy to move and can be carried out locally at low cost.
The results obtained show that the daily biogas production (1.564 m3 / d) during the anaerobic digestion process complies with the standards for the biogas potential of cow dung. The biogas produced has been tested to heat water and roast eggs.

Monitoring the digestion parameters (temperature and pressure) reveals that it is necessary to thermally insulate the tank (digester) or to place it in an isothermal chamber favorable to the development of metagenesis bacteria. Monitoring of the change in pH showed three phases (acidification, alkanization and stabilization).

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