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Realities, Potential And Availability Of Slaughterhouse Waste: A Guarantee Of Sustainable Development From Agroenergy Valorization By Biomethanization. Case Of Ankadindratombo, Rural Commune Of Alasora Madagascar

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Abstract – In order to develop the country, non-oil producing countries practice the policy of diversifying energy sources, as is the case with the valorization of slaughterhouse waste in Ankadindratombo, in the rural commune of Alasora, Analamanga region. This slaughterhouse has daily fermentable waste of 4360 kg from the slaughter of 100 heads of zebus and 20 heads of pigs. These wastes are not valorized until now, but they are potential resources for the development of the said commune. This research work has made it possible to valorize this waste by the technology of biomethanization. The infrastructure to be set up requires a digester with a useful volume of 91560 l or 92 m^3. The proposed model is the type of digester with floating bell. This valorization will make it possible to obtain 5958,67 kg of biological fertilizer per day and 74 127 l per month of biomethane gas, an alternative energy source to wood energy. The financial study showed that the implementation of this infrastructure requires an initial investment of 125 120 940 Ar, with a Net Present Value of 39 230 217,17 MGA, an Index of Profitability (Ip) of 1,31 and Internal Rate of Return (IRR) of 39, 7%.

In short, this research work is a contribution to the search for a viable and reliable solution to valorize the waste of slaughterhouses of Ankadindratombo for agro energy purposes.

Keywords – slaughterhouse waste, valorization, methanization, biogas, biological fertilizer, financial profitability

I. Introduction

Since the beginning of time, man has been looking for a potential, reliable, ecological energy resource to facilitate his daily life, whether in the form of heat, which was manifested through the flame in the time of the cavemen, or in a more advanced form such as electric light in our time.

These needs have been solved by many alternatives such as fossil energy and many others, but over the years, despite the high cost of hydrocarbons and polluting, another type of energy source is emerging due to its ecological character, inexhaustible and obtained from natural resources, it is the renewable energy such as biomethane. The use of the latter constitutes an appropriate solution to the satisfaction of the energy demand that our country is unable to meet. Indeed, Madagascar is full of exploitable raw materials in terms of green energy but many of them have not been treated as is the case of slaughterhouse waste of large cities of

Madagascar where tons of organic waste are stored and not valued yet they are potential resources, available daily and can not only be transformed into biomethane, a source of energy alternative to wood energy or in the form of agricultural fertilizer / biological fertilizer after passing through the technology of biomethanization.

The rural commune of Alasora, district of Antananarivo Avaradrano in the Analamanga region, located 7 km south of Antananarivo city, is home to the Ankadindratombo slaughterhouse.

The Ankadindratombo slaughterhouse slaughters one hundred (100) head of zebu and twenty (20) head of pigs every day to supply the butcher shops in the 1st and 2nd Arrondissement of the urban commune of Antananarivo. Each killed zebu generates 30 kg of cow dung and an average of 40 to 50 l of water for washing and other cleaning needs, i.e. about 70 kg of cow dung and slurry mixture. After calculation, the slaughterhouse has 7 tons of waste generated daily that emit a nauseating smell in the immediate vicinity of the said slaughterhouse because of the storage of this waste in a pit located in the enclosure. Since the beginning of the activity of the slaughterhouse until today, no idea of valorization of these wastes has been proposed.

In front of this situation, questions arise among others:

Is the valorization of this organic waste technically feasible?

What is the appropriate technology for the recovery of this fermentable waste from the slaughterhouse?

Taking into account the daily flow of waste from the plant, what is the required size of the biomethane production unit?

What is the investment required for the implementation of a biomethane unit within the slaughterhouse to satisfy their energy needs and is it financially profitable?

The present manuscript triortance of its valorization for agro energetic purposes on the one hand and on the other hand to the various economic and environments to contribute to the valorization of these wastes of the Ankadindratombo slaughterhouse through the highlighting of the impal advantages/benefits brought there.

II. Material And Methods

2.1. Study area

The Rural Commune of Alasora is located 7 km from the Urban Commune of Antananarivo in the district of Antananarivo Avaradrano. It is located in the district of Ankadindratombo and is in the Rural Commune of Alasora. It has an area of about 44 and is very populated with a population of 5821 inhabitants and a density of 3880 inhabitants/km2 for only 1.50 km2 of area. This slaughterhouse of Ankadindratombo existed since 1972 and was created by a group of butchers to avoid going to the slaughterhouse of Antananarivo, the only accredited slaughterhouse for the Capital and its surroundings at that time. At that time, the daily slaughter represented only 4 to 10 heads to supply the market of Ankadindratombo. But since 1990, butchers have increased in number and the meat supply area has continued to grow (Ambohipo, Ambanidia, Analakely...). As a result, the existence of the slaughterhouse was formalized by the assignment of a veterinarian in charge of the application of the texts in force (hygiene, stamping...) by the Service of the Ministry of Livestock. It was the first authorized regulatory slaughter in the Fivondronana of Antananarivo Avaradrano.

The Ankadindratombo slaughterhouse is located about 4 km from the rural commune of Alasora and 1.5 km from the Mandroseza Bridge. Figure 1 shows the location of the Ankadindratombo massacre.

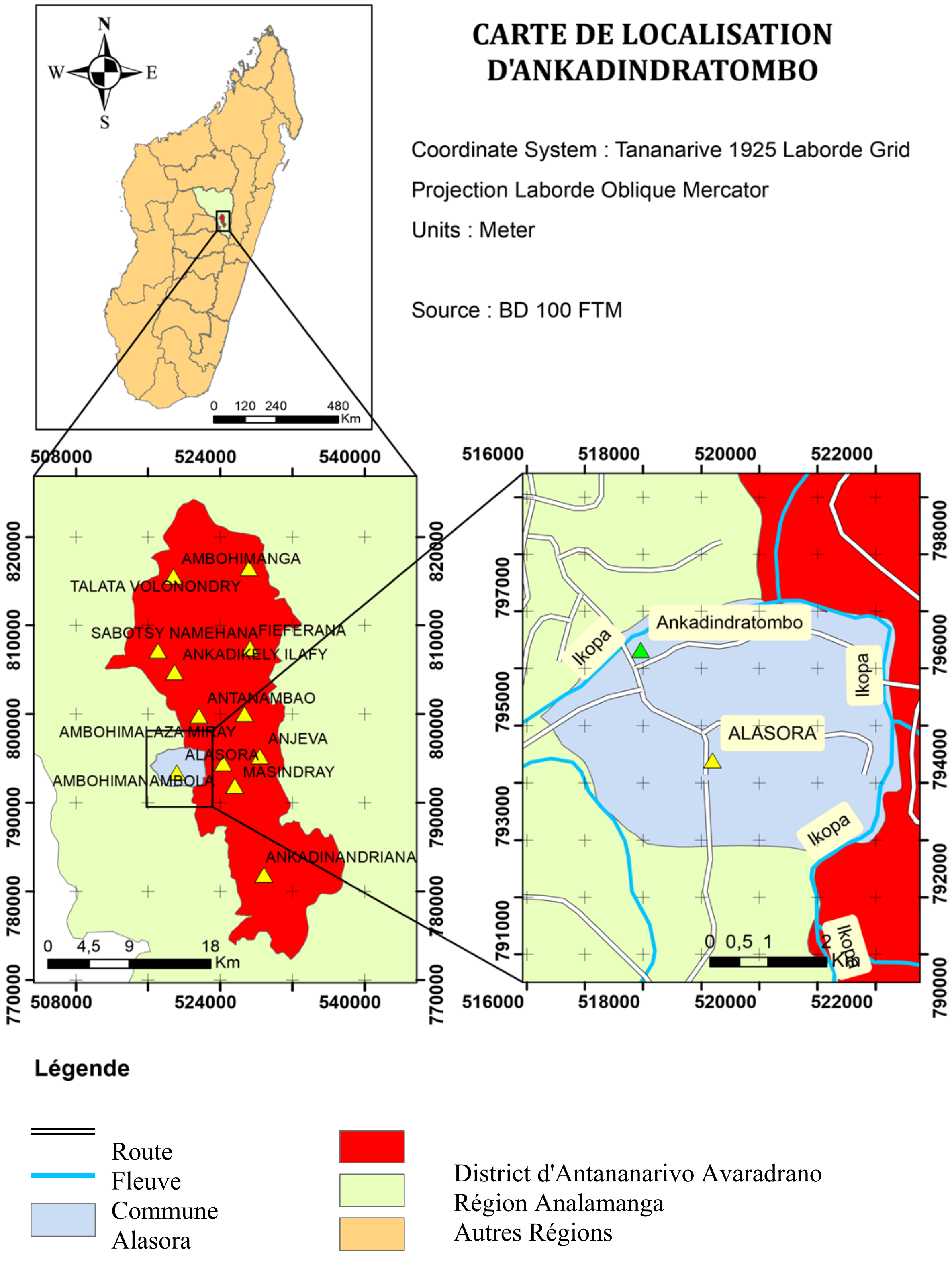

Figure 1: Location map of Ankadidrantombo (Source: BD 100 FTM)

2.2. Activities of the slaughterhouse

The Ankadindratombo slaughterhouse is a buying center, which means that cattle are bought, killed and sold. Its main activity is to kill cattle and pigs to supply the population of Antananarivo and its surroundings with meat. So far, there is no export activity. Moreover, it creates jobs for the population because there are at least 300 people working every day at the slaughterhouse.

There are three types of workers:

- Employees of the Rural Commune of Alasora

- Slaughterers

- Salesmen.

The slaughterhouse is under the management of the rural commune of Alasora because it is a public place, but private slaughterers work there. There is the tax and the right of slaughter and character (by the visit of the cattle) that must be paid to the commune through the tax collector.

The cattle come from the regions of Ihorombe, Melaky, Menabe, Sofia, Amoron'i Mania and sometimes from Analamanga. The meat is destined for the Analamanga Region, in supermarkets and sometimes for the district of Moramanga and the SHERITT Company in Ambatovy.

Figures 2 and 3 present respectively the number of oxen and pigs slaughtered for the year 2017, 2018 and 2019.

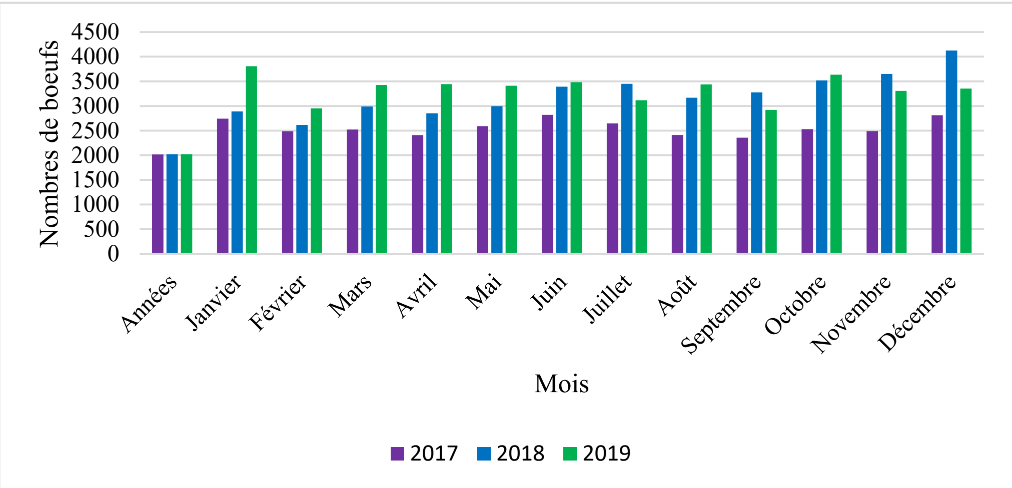

Figure 2: Representative curves of the number of oxen slaughtered

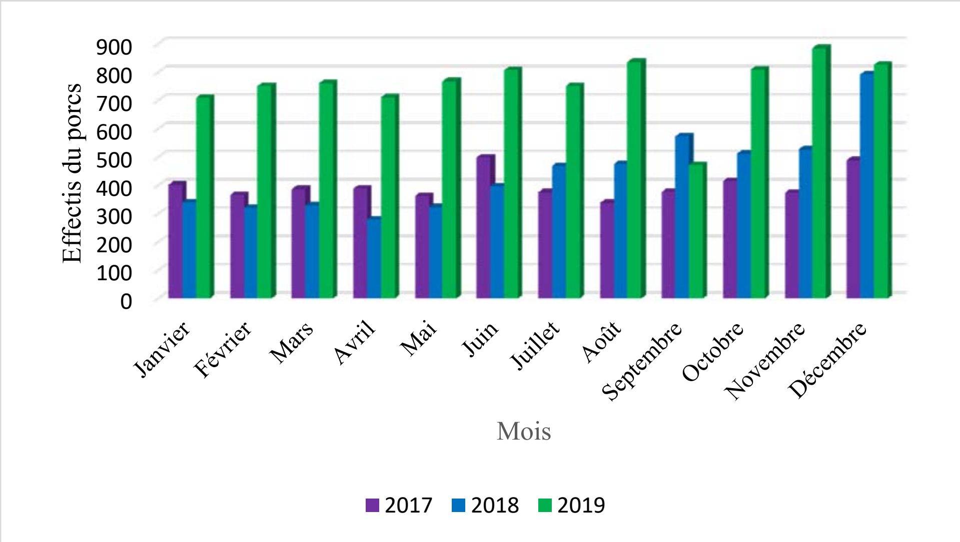

Figure 3 : number of pigs slaughtered

2.3. Fermentable waste from the slaughterhouse

2.3.1. Generalities

Fermentable waste is mainly made up of organic, animal or vegetable matter at different stages of aerobic or anaerobic fermentation. Animal waste is: Cow dung, cattle manure and pig waste.

These wastes are highly fermentable. Their storage in the enclosure of the slaughterhouse before finding buyers who are uncertain, generates unbearable odors that could affect the health of the surroundings. The valorization by technology of biomethanization is the best solution to avoid these stinking smells.

- Waste management policies for the Ankadindratombo slaughterhouse

In the event that no buyer is found, the waste from the Ankadindratombo slaughterhouse is transported to the Ikopa River via the irrigation canal or dumped in Ambohinonoka, which is located about 6 km from the slaughterhouse, because to date there is no conceivable project for its transformation, which obviously requires a large budget. Among the buyers, we can mention respectively the farmers who come from the respective districts of Manjakandriana, Ambatolampy, Arivonimamo and sometimes the company Guanomad and Mon Jardin which are the most beneficial because they get these wastes for free..

Organic waste potential of the Ankadindratombo slaughterhouse The Ankadindratombo slaughterhouse slaughters 100 head of zebu and 20 pigs each day. It is estimated that a zebu generates 40 kg/d of waste and a pig produces an average of 18 kg/d. It should be noted that the amount of waste is a function of the livestock unit (LU) of each animal.

For 100 zebus killed per day, the amount of waste is 100 x 40kg/d/animal = 4,000kg/d .For the 20 pigs killed per day, the amount of waste generated is 20 x 18 kg/d/animal =360 kg/d. Adding up the waste from the 100 oxen and 20 pigs killed in the slaughterhouse, we will have a total of 4000 + 360 = 4360 kg/d of fermentable waste.

Biomethane production process: Methanization

Methanization takes place in 4 successive stages which are hydrolysis, acidogenesis, acetogenesis and methanogenesis; the specific microorganisms of the first stages serve as substrates for the following stages:

Hydrolysis:

The hydrolysis step is an extracellular enzymatic step in which the macromolecules from the disaggregation step are reduced to monomers in the following way:

Polysaccharides are transformed into monosaccharides;

Lipids are transformed into long chains of fatty acids;

Proteins are transformed into amino acids;

Nucleic acids are transformed into nitrogenous bases

Acidogenesis:

During this stage, the products of hydrolysis are absorbed by fermentative bacteria which metabolize the monomers to produce volatile fatty acids (VFA) (acetate, propionate, butyrate, isobutyrate, valerate and isovalerate), alcohols, dihydrogen sulfide (H_2S), responsible for the odor, characteristic of methanizers, carbon dioxide (CO_2), and hydrogen (H_2). Thus, we obtain simplified fermented products. This step is very fast and the bacteria involved have a very short duplication time compared to other steps and a higher duplication rate compared to other populations of bacteria. Also, there can be an accumulation of these intermediate products of anaerobic digestion which can destabilize and stop the other stages because of the inhibiting power of a too great concentration of these elements.

Acetogenesis:

During this stage, the products of acidogenesis are transformed by acetogenic bacteria into acetate, carbon dioxide, and hydrogen. The time of progress of these bacteria is much longer than those of the acidogenesis.

Methanogenesis:

During this step, the products of the previous reactions, mainly acetate, formate, carbon dioxide and hydrogen, are converted into methane by the so-called methanogenic bacteria. Their splitting time is slightly faster than the populations of acetogenic bacteria.

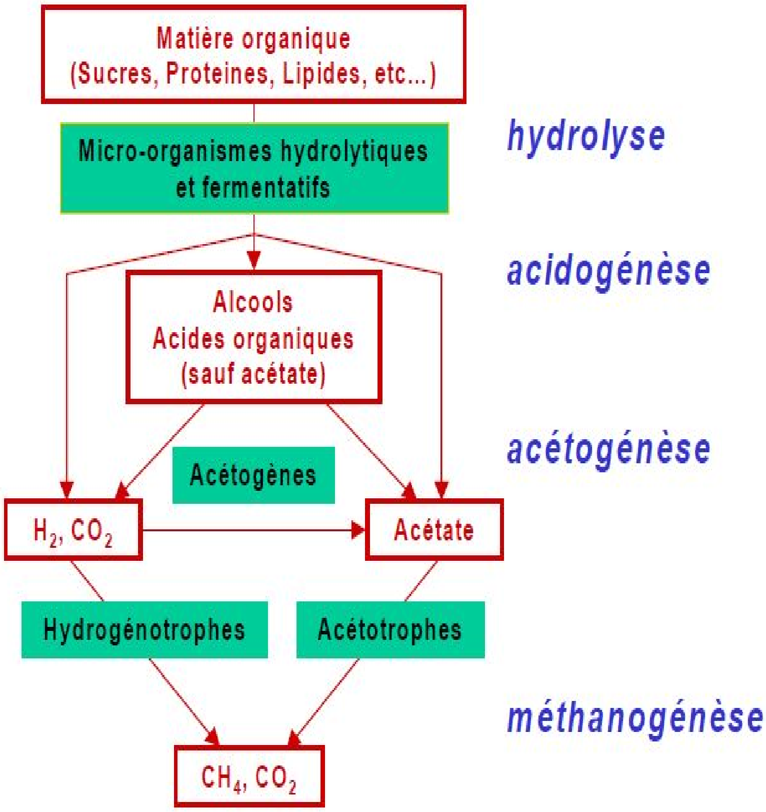

Figure 4: The different stages of anaerobic digestion

Methodologies

This section details the different activities followed for the experimental studies undertaken in chronological order.

2.5.1. Experimental study of biomethane production from slaughterhouse waste in Ankadindratombo:

Prior to the experimental trials for biomethane production, the samples were analyzed at the FOFIFA soil laboratory and the Centre National de Recherches Industrielle et Technologique (CNRIT) to determine respectively:

- The rate of organic carbon ;
- The rate of Nitrogen;
- The C/N ratio

2.5.1.1. Determination of organic carbon content

Principle:

The organic carbons are oxidized in excess by potassium dichromate solution () in acid medium. The excess will then be determined with a ferrous sulfate solution (, 7). The end of the reaction is observed by the change of an intense green coloration to purplish red. The corresponding reactions are as follows:

Equation 1: Oxidation-reduction: Organic carbon

C (org) + $O_2 \rightleftharpoons CO_2 + 4\,e^-$

$Cr_2\,O_7{}^{2-} + H^+ + 6\,e^- \rightleftharpoons 2\,Cr^{3+} + 7\,H_2O$

Oxydation de C organique

$Fe^{2+} \rightleftharpoons Fe^{3+} + e^-$

$Cr_2\,O_7{}^{2-} + 14H^+ + 6\,e^- \rightleftharpoons 2\,Cr^{3+} + 7\,H_2O$

Titrage de l'excès de bichromate

Analytical procedure:

Take 0.5 g of well ground sample of 0.5 mm diameter pellet and put it in a 250 ml Erlenmeyer flask adding 10 ml of 1N potassium dichromate. Swirl the Erlenmeyer until the sample is dissolved then 20 ml of concentrate was added quickly followed by stirring for one minute. Let the sample stand for 30 minutes to cool. Then 200 ml of distilled water and 4 drops of orthophenantroline were added. Then the solution was titrated with 0.5N. The end of the reaction is observed by a color change: from intense green to purplish red.

Calculation :

we have:

$$\text{Carbone organique (C \%)} = \frac{(N_{Ox}V_{Ox} - N_{réd}V_{réd}).0{,}39}{masse\ d'échantillon}$$

Où :

Masse d'échantillon est en g
$V_{réd}$ en ml
Ox : bichromate de potassium
Réd : sulfate ferreux

The rate of organic matter being obtained by the following simplified formula:

=>

$$\text{Matière Organique (M.O\%)} = \text{Carbone (C\%)} \times 1.72$$

2.5.1.2. Determination of the Nitrogen rate

Principle

The substance is heated with concentrated sulfuric acid which, when boiling, destroys the nitrogenous organic matter. Carbon and hydrogen are released as CO_2 and H_2O, the nitrogen transformed into ammonia is fixed by the sulfuric acid as $(NH_4)_2SO_4$. K_2SO_4 raises the boiling temperature of H_2SO_4 to 430°C. $CuSO_4$ serves as a catalyst. NH_3 is then displaced by a sodium hydroxide solution, entrained in steam and fixed in the borate state, which is determined by a titrated solution of sulfuric acid.

Reagents

- Concentrated sulfuric acid (H_2SO_4)

- Kjeltab mineralization catalyst: mixture of 3.5 g of K_2SO_4 and 0.4 g of ($CuSO_4$, $5H_2O$) per sample.

- 10 N sodium hydroxide solution

- Sulfuric acid solution 0.01 N

- Mixed indicator: dissolve 0.0495 g of bromocresol green and 0.033 g of methyl red in 50 ml of ethanol.

- 2% boric acid solution: In a 2 l volumetric flask, dissolve 40 g of H_3BO_3 in 1800 ml of distilled water. Then add 40 ml of the mixed indicator solution. Mix and adjust the volume with distilled water to the mark of the dipstick.

Operating mode

Mineralization

Pour 20 ml of H_2SO_4 in the Matra, add O,5g of sample and two catalysts (Copper Sulfate and Potassium Sulfate). Then, let it stand for a few minutes until the color turns brown, then put it in a mineralizer for 4 hours and the color of the mineralization obtained becomes light green.

Distillation

To make the distillation, first prepare a trap solution to trap the Ammonia (NH_3) contained in the mineralizate. It is a mixture of 25 ml of boric acid, a few drops of colored indicator and distilled water. Then, the distillate is added with 20 ml of distilled water and 50 ml of soda.

The soda (NaOH) which is in excess releases ammonia (NH_3) which condenses as a vapor. When passing through the refrigerator it becomes a liquid and migrates into the trap solution. The solution obtained is called distillate or ammonium borate.

Titration

The distillate obtained is then titrated with 0.1N H_2SO_4 until the green color turns to pink.

Calculation

The nitrogen content in a sample can be calculated by the following formula:

We know that:

$$\%N = \frac{V.0,07}{P.E}$$

With

V : volume versée d'H_2SO_4
P.E : Poids de l'échantillon

2.5.1.3. Determination of the C/N ratio

The principle of the C/N ratio is to determine the time of the degradation of the substrate if it is slow. The optimum C/N ratio is equal to 30, if the C/N ratio of the substrate is higher than 30 the substrate is difficult to decompose and the production of biogas is slow and if the C/N ratio is lower than 30 the gas provided can be toxic because there is presence of ammonia.

We have: $R=\frac{\%C}{\%N}$ where:

C : carbon content
N : sample weight

Process of biomethane production by biomethanization in the laboratory of the CNRIT Energy Department

The process of biomethane production in the laboratory is divided into several steps and is as follows:

1st step: After having obtained samples of fermentable waste (cow dung, beef manure) it is necessary to pass to the successive weighing of these raw materials taken in the slaughterhouse of Ankadindratombo and we put them in three glass bottles of laboratories called Biodigester of laboratory (BD):

- First biodigester (BD N°1): cow dung to 1 kg in 3.70 kg;

- Second biodigester (BD N°2): ox manure at 1 kg in 2,615 kg;

- Third biodigester (BD N°3): we mix cow dung of mass: 500 g in 3,70 kg and ox manure of mass 500 g in 2,615 kg.

The raw materials are mixed well in each biodigester with drinking water, as this is essential for the gas production phase. The volume of water mixed with the raw materials should be 2/3 of the biodigester volume.

The temperature of the water in the biodigester is between 32 ºC and 35 ºC. A temperature regulator automatically controls the operation of the resistance that heats the water. Inside the tank there is a temperature probe that sends a signal to the regulator.

Checking the gasometer, the recovery tank and the resistance is necessary to avoid leaks if they exist.

After all this, it is necessary to note the time of the start and then to follow the evolution of the biomethane production every 24 hours.

Table 1: Biomethane production process by biomethanization at CNRIT laboratory

 *Photo 1 : digesteurs vides*	 *Photo 2 : Ajout d'eau et de substrat*	 *Photo 3 : Homogénéisation des substrats avec l'eau*
 *Photo 4 : Trois digesteurs remplis d'eau et de substrat*	 *Photo 5 : Bac d'immersion*	 *Photo 6 : Bac de récupération*
 *Photo 7 : Régulateur de la résistance*	 *Photo 8 : Gazomètre*	 *Photo 9 : Vue d'ensemble des matériels au CNRIT*

Study of the sizing of the biomethane reactor in adequacy with the daily waste flow of the Ankadindratombo slaughterhouse

Previously known that the slaughterhouse of Ankadindratombo slaughters 100 oxen and 20 pigs per day and produces 4360 kg/d of fermentable waste. To valorize these 4360 kg/d of waste, the installation of a valorization unit is the best solution.

What is the volume of biodigester required for this waste?

By applying the following formula: Vb = D x TRH with:

Vb= Volume of the biodigester

D= Daily flow rate

TRH = Hydraulic Retention Rate

Application: D = 4360 kg/d; TRH= 21 d

Thus: V= 91560 l that is to say: 91, 560 m^3

Therefore, the valorization of these 4360 kg/d of fermentable waste requires the implementation of a biomethane unit with a useful volume of 92 m^3.

Model of the biomethane unit

Several models are possible for this plant for the satisfaction of their daily energy needs such as the model with separate tank, fixed dome, plug flow and floating bell. As each model has its own specificity, so we propose a model with floating bell because this model is able to use any device at different pressures of use even if its cost is a little expensive compared to other known model.

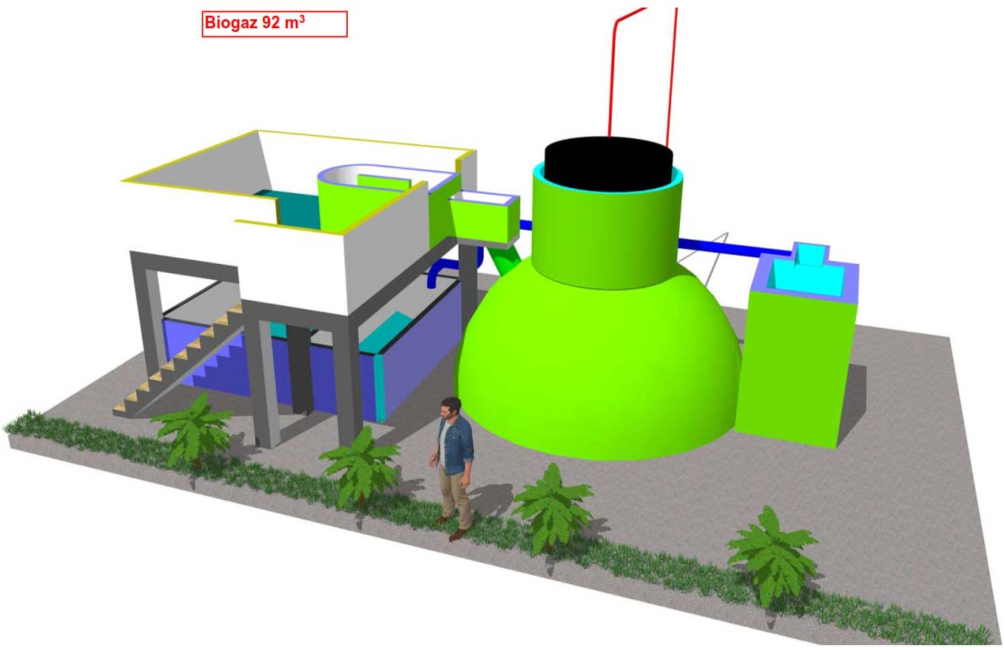

Figure 5: Components of a biodigester

III. Results And Discussions

3.1. Experimental results

3.1.1. Organic characteristics of raw materials

This table 2 shows the organic characteristics of cow dung and cattle manure

Table 2: organic characteristics of cow dung and cattle manure

	cow dung	Beef manure	Mixture of cow dung and beef manure
Rapport C/N	40,66	32,10	18,08
pH	6,99	7,48	7,45
%C	35,895%	42,573%	29,3
%N	1,118%	1,047%	1,62

3.1.2. Result of the gas production experiment

The experiment made at the CNRIT laboratory allows us to obtain the table 3, summarizing the daily evolution of biomethane

Table 3: Summary of biomethane production

	Cow dung	Beef manure	Mixture of cow dung and beef manure
Monthly production (cm3/month)	3605,37	4048,9	2007,10
Daily production (cm3/d)	349,74	412,13	204,35

3.1.3. Evolution curves of biomethane gas

The experiment made at the CNRIT laboratory allows us to obtain the results summarized in figures 6, 7 and 8. They present the curves of daily evolution of biomethane, the quantity of gas and its cumulative evolution.

These first curves show the sampling of raw materials during the experiment

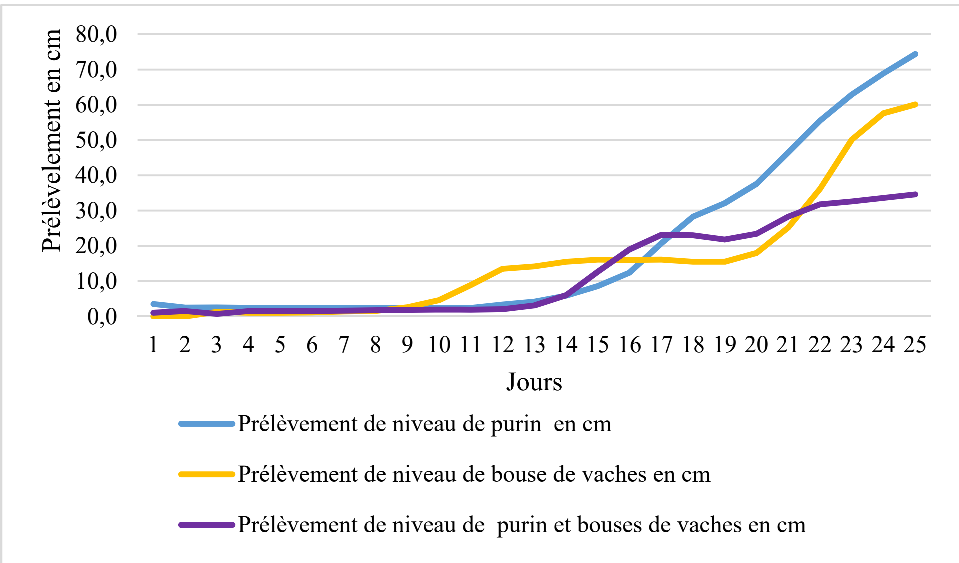

Figure 6: Daily evolution of biogas

These second curves will show the variation of the gas quantities of the substrates:

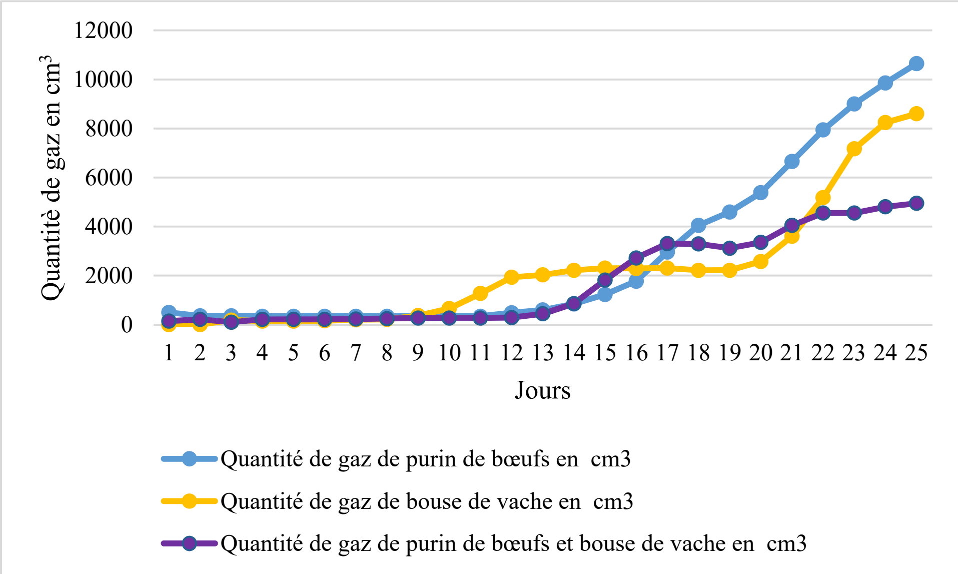

Figure 7: Representative curve of gas quantities

Thus, these third curves will reveal the evolution of the cumulative gas volumes per day:

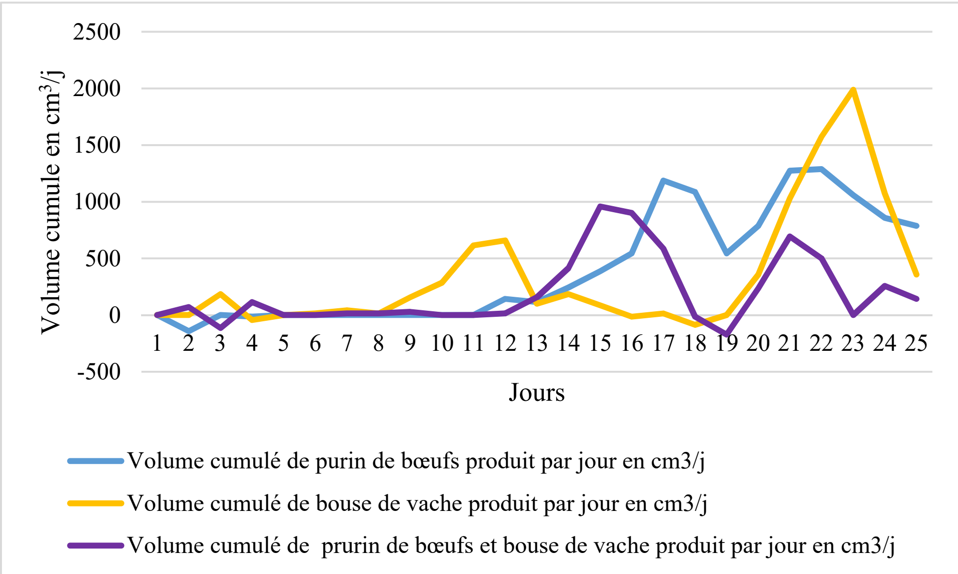

Figure 8: Representative curve of the evolution of cumulative gas volumes per day

3.1.4 Results of agricultural fertilizer production (organic fertilizer)

Table 4 summarizes the results of the lab experiment with those of the real environment.

Table 4: biological fertilizer Product

Designation	**Result of the lab experiment**	**Result of the operation in real environment**
waste (kg/d)	1	4360
ferment (10%) (kg)	0,1	436
Water (l)	3	13080
Reactor volume (l)	5	91 560
Forecasted biogas production (l)		
In a 30 day cycle (l)	4,048	74 127
In one year : (12 cycles of 30 days (l)	48,576	889 524

This table 4 shows that the valorization of the slaughterhouse waste of Ankadindratombo will make it possible to dispose of 5958.67 kg of biological fertilizer/fertilizer per day, i.e. 5.95867 tons per day corresponding to the difference between the sum of the daily flow, of the ferment (10%) and of the water with 2/3 of this sum.

3.2 Investment required and profitability indicators for the implementation of the biodigester

The valorization of the daily waste of the slaughterhouse requires a biodigester of useful volume of 92 m^3 requiring an initial investment of 125,120,940 Ar, with a Net Present Value of 39,230,217.17 MGA, an Index of Profitability (Ip) of 1.31 and Internal Rate of Return (IRR) of 39.7%.

IV. Conclusion

This research work has confirmed that fermentable slaughterhouse waste can be used for agro-energy purposes. Cattle dung and liquid manure are resources suitable for producing biomethane, a source of domestic energy. Methanoic fermentation or biomethanization is the appropriate technology to valorize these slaughterhouse wastes. The methodology adopted for the concretization of this work consists in going through the following activities in chronological order: bibliographic and webography research on biomethanization, the field trip to the rural commune of Alasora and to the slaughterhouse of Ankadindratombo to see the study site closely, to investigate the slaughterhouse manager on their daily activity and to take samples of cattle dung and liquid manure for the experimental tests in the laboratory. These samples were sent to the FOFIFA soil laboratory in Fiadanana Tsimbazaza to characterize the dry matter (DM) content and the carbon to nitrogen (C/N) ratio, respectively. The samples were then tested in the laboratory of the CNRIT energy department for the anaerobic fermentation of cattle dung, slurry and the mixture of dung and slurry. The result of this work allowed to say that: Firstly, the slaughterhouse of Ankadindratombo kills on average for the three years (2017, 2018 and 2019) 34771 oxen and 6402 pigs; secondly, the productivity of biogas from laboratory digester made at the CNRIT corresponds well to that obtained from large biogas unit cited in the literature; thirdly, the manure with a C/N ratio of 44.74, produces more biogas with 425.77 cm3 than the cattle dung with a C/N ratio of 38 and a daily production of 343.93 cm3/d. The mixture of the two samples (liquid manure + cattle dung) is not interesting, as it produces only 198 cm3/d. The realization of the treatment infrastructure for the recovery of slaughterhouse waste requires an initial investment of 125,120,940 Ar, with a Net Present Value (NPV) of 39,230,217.17 Ar, a Profitability Index (PI) of 1.31 and an Internal Rate of Return (IRR) of 39.7%. In short, even though non-oil producing countries do not have a reliable source of energy for their development, the diversification of energy sources is the most appropriate policy. Much remains to be done for this research work among others the mixing of this slaughterhouse waste with household waste or latrine which are organic materials with respectively different C/N ratio and dry matter rate.

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