ORIGINAL ARTICLE

Energy Potential of the biodigestor Installed in the Santa Barbara Farm, Sumapaz Province, Colombia

Potencial energético de biodigestor instalado en la finca Santa Bárbara, provincia de Sumapaz, Colombia

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ABSTRACT: This research is oriented towards determining the energy potential of a biodigester installed on the Santa Bárbara farm, which is located in the Sumapaz province, Colombia. For this, the existing animal species in the scenario is determined, which will contribute organic waste to the biodigester, the number of animals is also determined, considering the herd movement, which would make it possible to determine the biomass generated daily, with the purpose of establishing the sizing of the appropriate biodigester technology and knowing the behavior of the energy parameters. Among the main results obtained, it was evidenced that the biodigester installed by the producer is not capable of assimilating the biomass generated daily, due to the number of existing animals; noting that despite the fact that only approximately 35% of the energy potential is used, due to the dimensioning of the anaerobic digestion technology (tubular polyethylene biodigester) installed in the Santa Bárbara farm, despite this it is shown that it contributes to saving energy and the conservation and preservation of the environment. However, if the biodigester designed in the research were installed, the energy potential would be used 100%, validating that the adequate dimensioning of the anaerobic digestion technology is proportional to the energy savings to be obtained in agricultural units.

Keywords: renewable energy, pig production, anaerobic digestion, energy feasibility, environmental impact.

RESUMEN: La presente investigación se orienta en la determinación del potencial energético de un biodigestor instalado en la finca Santa Bárbara, la cual se localiza en la provincia Sumapaz, Colombia. Para ello se determina la especie animal existente en el escenario, dado que aportará los residuos orgánicos hacia el biodigestor, también se determina la cantidad de animales, considerándose el movimiento de rebaño, lo cual posibilitaría determinar la biomasa generada diariamente con el propósito de establecer el dimensionamiento de la tecnología de biodigestor adecuada y conocer el comportamiento de los parámetros energéticos. Entre los principales resultados obtenidos, se evidenció que el biodigestor instalado por el productor, no es capaz de asimilar la biomasa generada diariamente, debido a la cantidad de animales existentes; observándose que a pesar de que solo se aprovecha aproximadamente el 35% del potencial energético, debido al dimensionamiento de la tecnología de digestión anaerobia (biodigestor tubular de polietileno) instalada en la finca Santa Bárbara, a pesar de ello se demuestra que se contribuye al ahorro energético y a la conservación y preservación del medioambiente. Sin embargo, si fuese instalado el biodigestor diseñado en la investigación, el potencial energético se aprovecharía en un 100%, validándose que el dimensionamiento adecuado de la tecnología de digestión anaerobia es proporcional al ahorro energético a obtener en unidades agropecuarias.

Palabras clave: energía renovable, producción porcina, digestión anaerobia, factibilidad energética, impacto ambiental.

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INTRODUCTION

It is currently known that the high rate of consumption of non-renewable resources is a worrying issue worldwide, due to the exploitation and consumption of fossil fuels (oil, coal, natural gas, liquefied petroleum gas and uranium) and the high level of pollution and environmental impact they generate. The current world faces two basic problems for the existence and future progress of humanity: stopping the growing environmental pollution and finding and obtaining new sources of energy (Guardado, 2006; Varnero, 2011). The only way to have a secure energy future is to find an environmentally sustainable way to produce and use energy. If society's concerns about energy and the natural environment are not addressed, the steady and secure energy supply on which economies depend will be jeopardized (Priddle, 1999). It is necessary to take advantage of renewable energy sources based on the best use of local resources which, through the best use of appropriate technologies contribute to saving conventional fuel and serve to return the nutrients it needs to the soil and preserve the environment from contamination (Santos *et al.* , 2012).

A clear example of renewable energy sources is biomass, a term that refers to all the organic matter generated from photosynthesis or produced by the food chain. And as a raw material for recycling processes: its origin is the recently expelled feces and urine (animal excrement), which are made up of the leftover food already digested, but not used by the body, apart from waste such as beds, food residue or added material (Grundey & Juanos, 1982).

The use of biomass in different alternative forms, to provide a response to energy demands is a satisfactory option. Biomass for its use as an energy material, requires an adaptation that facilitates the application of the selected process, to obtain the required fuel. According to Fonte (2004); Arauzo *et al.* (2014); Singh *et al.* (2016), the processes to convert biomass into fuel are: Mechanical (sawdust, briquettes), Thermochemical (pyrolysis, gasification and incineration) and Biotechnological (alcoholic fermentation, anaerobic digestion).

Anaerobic digestion is a good alternative to treat waste with high biodegradable organic matter (Flotats *et al.* , 2001; Sosa, 2017). Therefore, according to Suárez *et al.* (2018) this treatment is indicated for agro-industrial wastewater, with a high load of biodegradable organic matter: discharges from the production of sugar, alcohol, meat, paper, preserves and distilleries Rahayu *et al.* (2015); agricultural residues, such as slurry, manure according to Bansal *et al.* (2017); and urban waste that includes both the organic fraction of solid waste according to Biogas Association Ottawa (2015) and urban wastewater treatment plant sludge (Frankiewicz, 2015).

Precisely the biodigester is anthropogenically (produced by human activity) the technology to highlight in the biotechnological process of anaerobic digestion of biomass to obtain biogas. It is a hermetic reactor with a side inlet for organic matter, an outlet at the top through which biogas flows, and an outlet for obtaining effluents with biofertilizing properties, both products contributing to meeting the needs of producers and promoting of organic agriculture, as an economically feasible and ecologically sustainable alternative (Zheng *et al.* , 2012).

To these aspects should be added the high prices of fuels and the high local rates of electricity, being factors to consider for the introduction of biodigesters or biogas plants at the national and regional level that produce energy from the use of waste of agricultural production (Parra *et al.* , 2019).

Considering the previously described criteria, in the Santa Bárbara farm located in the capital Fusagasugá, of the Sumapaz province, Colombia, a biodigester was installed with the objective of producing biogas and biofertilizers, for which the objective of the present investigation was oriented in determining the energetic potentialities of the use of this technology in this productive system.

MATERIALS AND METHODS

Characterization of the Santa Bárbara Farm

The Santa Bárbara farm is located in the capital Fusagasugá, Sumapaz province, Colombia, it is a private property, and has a total area of 5,5 ha, where cattle and pigs are raised, in the specific case of the pig cattle, has a total of 992 animals, broken down into the following categories: 106 breeders, 22 suckling pigs, 808 fattening and 56 pre-fattening. The main pig crosses are: F1 (Landrace x Large withe) x PIC 337; Pietran x PIC 337. The diet of these cattle is made up of: Concentrated flour feed made with raw materials such as: American corn, soybean cake, palm oil, Mogolla wheat, Molasses, Calcium carbonate and Nuclei (commercial amino acids with vitamins). The behavior of temperature and humidity varies depending on the time of year, obtaining the following values according to climate variability: in climates: Warm: 24 °C to 28 °C (9.21%), in Temperate climate: 18 °C to 23 °C (54%) Cold: 12 °C to 18 °C (32.2%).

Methodology for the sizing and installation of tubular polyethylene biodigesters

For the calculation of the design parameters of a polyethylene tubular biodigester, it is necessary to know the input data, and those that must be determined (Table 1).

The daily amount of material (Bmd) is directly related to the amount of biomass that is generated, whether it is domestic, agricultural or animal waste. In

TABLE 1. Input and output data required for the design of an anaerobic biodigester.

Parameters	Unit
Input data	
Daily amount of material (Bm_d)	kg day^{-1}
Excreta-water ratio (N)	L kg^{-1}
Biogas yield(Y)	m^3 kg^{-1}
Hydraulic retention time (TRH)	day
output data	
Daily volume of material (mixture of excreta and water)(Vdm)	kg day $^{-1}$
Biodigester volume, (V_{biodig})	m^3
Daily volume of biogas produced (G)	m^3 day $^{-1}$
Biogas holding volume (V_2)	m^3
Compensation tank volume(Vtc)	m^3

addition, the maximum amount obtained and the production increase plans must be taken into account.

The amount of daily biomass generated (Bmd), is determined through the following expression:

$$Bm_d = Ca \times Ce \times Rp \times Rt, kg.day^{-1} \quad (1)$$

where: Ca- Number of animals; Ce-Amount of excreta per animal, kg/day; Rp- Ratio between the average live weight of the animal population and the tabulated equivalent live weight; Rt- Fraction between the lairage time with respect to the duration of the day, h/day

$$Bm_d = Ca \times Ce \times \left(\frac{PVp}{PVe}\right) \times \left(\frac{Te}{24h}\right), kg.day^{-1} \quad (2)$$

where: PVp-Average live weight of the animal population, kg; PVe- Tabulated live weight equivalent; Te-Hours of the day that the animal remains stabled, h/day

The daily volume of material (mixture of excreta and water) (Vdm), is nothing more than the sum of the residual and the dilution of the biomass (residual and water).

$$\text{Vdm} = (1 + N) \cdot Bmd, m^3.day^{-1} \quad (3)$$

where: N: Excreta-water ratio, L/ kg, it is required to know that the density of water is: 1000 kg/m^3.

While, the volume of the biodigester (V_{biodig}) is calculated taking into account the value of the volume of material (mixture of manure and water) Vdm that enters the biodigester and the retention time TRH.

$$V_{biodig} = \text{Vdm} \cdot TRH, m^3 \quad (4)$$

Subsequently, the daily volume of biogas (G) produced is calculated:

$$G = Y \times B_{md}, m^3.day^{-1} \quad (5)$$

where: Y- Biogas yield, m^3. kg^{-1}

The biogas yield (Y), is determined by the expression:

$$Y = \frac{X}{C_e}, m^3.kg^{-1} \quad (6)$$

where: X- energy conversion coefficient of the excreta produced daily, that is, the daily production of biogas depending on the type of organic waste, m^3/day.

For all types of biodigesters, the volume of the compensation tank (Vtc) is equivalent to the volume of gas produced, that is, it ranges between 25…30% of the volume of the biodigester.

RESULTS AND DISCUSSION

Biodigester sizing.

For the correct sizing of the biodigester, the determination of the following parameters is required:

- Amount of daily biomass generated (Bmd);
- Daily volume of material (mixture of excreta and water) (Vdm);
- Volume of the biodigester (V_{biodig});
- Volume of the compensation tank (Vtc).

The results obtained from each of these parameters are represented in Table 2, these values are obtained from the herd movement conceived by the owner of the farm during the month of April 2022.

Potential energy input

To determine the potential energy, supply to be obtained based on the number of animals available, the determination of the following parameters is required:

- Biogas yield (Y);
- Daily volume of biogas (G).

Referring to Table 1, where it is shown that for every 50 kg of pig, 2,25 kg of excreta are obtained, generating 0,10 m^3 of biogas/day, with a ratio of 1:1-3 of excreta-water (taking a ratio of 1:1) and with a recommended retention time of 40 days, the sizing of the biodigester required for that number of animals (Table 2) and the energy contribution of the animal population (Table 3) were determined.

TABLE 1. Herd movement at the Santa Bárbara farm in the month of April/2022

Herd movement	Initial Existence	Final Existence	Animals/day	Average Mass, kg
Breeders	106	110	108	177
suckling pigs	22	48	34	110
fattening pigs	808	820	814	90
Pre-Fattening pigs	56	14	36	22
Total	**992**	**992**	**992**	**99**

TABLE 2. Sizing of the biodigester designed based on the number of animals

Raw material source	Animal / day	Average Mass, kg	Bmd, kg/day	Vdm, m³/day	V_{biodig}, m³	V_{tc}, m³
Breeders	108	177	860,2	1,72	68,8	22,7
suckling pigs	34	110	168,3	0,34	13,6	4,4
fattening pigs	814	90	3296,7	6,59	263,6	86,9
Pre-Fattening pigs	36	22	35,64	0,07	2,8	0,92
Total	**992**	**99**	**4 360,84**	**8,72**	**348,8**	**115,10**

TABLE 3. Energy contribution of the animal population

Raw material source	Animal / day	Average Mass, kg	Bmd, kg/day	Y, m³/kg	G, m³/day
Breeders	108	177	860,2		37,8
suckling pigs	34	110	168,3		7,5
fattening pigs	814	90	3296,7	0,044	145
Pre-Fattening pigs	36	22	35,6		1,5
Total	**992**	**99**	**4 360,8**		**191,8**

As evidenced in Table 2, the largest amount of daily biomass generated is obtained in the fattening category, representing 75,5% of the total amount of daily biomass generated. This result is mainly due to the number of animals in this category.

On the other hand, it is evident that the fattening category is the one that most influences the sizing of the biodigestion system, since it represents the highest representative percentage with respect to the volumes of the biodigester and compensation tank.

As shown in Table 3, the biogas yield to be obtained according to the species is 0,044 m³/kg (if the total number of animals is considered, 43,6 m³/kg is obtained) and for that number of stabled animals it is possible obtain a daily volume of total gas production of 191,8 m³/day.

However, a 120 m³ biodigester was installed on the farm (Figure 1), showing that it is less than the one that should be installed based on the number of existing animals and the amount of matter generated daily; This element considerably limits the energy potential of the scenario under study, which can be seen in Table 4.

As evidenced in Table 4, the installation of biodigesters in agricultural production units constitutes an energetically viable option, to which the contribution to the conservation and care of the environment should be added.

FIGURE 1. Biodigester installed at Santa Bárbara Farm.

It is valid to point out that the correct sizing of this type of technology favors the maximum use of the waste obtained in the productive scenarios, this criterion is based on the differences represented in the aforementioned table, evidencing that the farm does not take full advantage of the volume of waste from pig production. When carrying out a percentage analysis, it is obtained that with the digester installed by the producer, only approximately 35% of the energy potential to be obtained is used.

TABLE 4. Comparison between installed biodigester and biodigester designed according to the herd

Sizing Parameters	Installed biodigester	Biodigester designed	Difference
V_{biodig}, m^3	120	348,8	218
V_{tc}, m^3	39,2	115,1	75,5
V_{gas}, m^3	39,2	115,1	75,5
Energy parameters	**Installed biodigester**	**Biodigester designed**	**Difference**
Y, m^3/kg	0,044	0,044	0
G, m^3/día	71,2	191,8	120,6
Potential Energy Savings	**Installed biodigester**	**Biodigester designed**	**Difference**
Electric power, kWh	128,6	345,2	216,6
Natural Gas, m^3	42,7	115	72,3
Charcoal, kg	21,4	57,5	36,1
Wood, kg	192,2	517,8	325,6
Gasoline, L	56,9	153,4	96,5
Fuel Alcohol, L	85,4	230,2	114,8
Fuel oil, L	49,8	134,3	84,5

CONCLUSIONS

- Despite the fact that only approximately 35% of the energy potential is used, due to the dimensioning of the anaerobic digestion technology (tubular polyethylene biodigester) installed in the Santa Bárbara farm, it is shown that it contributes to energy savings and conservation and preservation of the environment.
- The design of the polyethylene tubular biodigester suitable for the farm is carried out, considering for this the number of animals (pigs) existing in it, the herd movement conceived by the producer and the amount of daily biomass generated.
- It is evident that the proper dimensioning of the anaerobic digestion technology is proportional to the energy savings to be obtained in agricultural units.

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