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Analysis of laying hen manure to turn electrical energy to meet household energy needs

I Ketut Perdana Putra [1,*] and I Gede Bawa Susana [2]

[1] *Department of Electrical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram-Nusa Tenggara Barat 83125, Indonesia.*
[2] *Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram-Nusa Tenggara Barat 83125, Indonesia.*

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Abstract

Laying hen manure has the potential as a renewable energy source through the biogas process. This study aims to analyze the possibility of laying hen manure as a source of electrical energy. The data used in this study came from a farm with a population of 2000 chickens. The research method includes calculating manure production, the potential for biogas produced, and estimating the electrical energy that can be converted from the biogas. The results showed that with 2000 chickens, around 240-300 kg of manure can be produced per day, which has the potential to produce 8.88-11.1 m3 of biogas. The electrical energy that can be made is estimated at 16-20 kWh per day. Thus, laying hen manure can be a sustainable alternative energy source.

Keywords: Chicken manure; Biogas; Electrical energy; Renewable energy

1. Introduction

Renewable energy is a solution to dependence on fossil fuels. One potential energy source is biogas produced from organic waste, including laying hen manure. Chicken manure has excellent potential as a renewable energy source through biogas production. The anaerobic process in chicken manure produces biogas rich in methane, which can be used as an alternative energy source. Biogas contains methane that can be converted into electrical energy through a biogas generator. Dependence on fossil fuels has caused various problems, including increased greenhouse gas emissions and unstable energy prices. Therefore, renewable energy is an increasingly being developed solution. One potential energy source is biogas produced from organic waste, including laying hen manure. Chicken manure has a high organic content, so it can be processed through an anaerobic fermentation process to produce biogas. The resulting biogas is rich in methane (CH4), which can be used as fuel or converted into electrical energy through a biogas generator. This process produces energy and reduces the environmental impact of poorly managed livestock waste [1].

Several studies have shown that chicken manure has excellent potential in biogas production. A study by [2] showed that 1 kg of chicken manure can produce around 0.03 m^3 of biogas. With a large chicken population, such as in this study, which included 2000 chickens, biogas production's potential is significant and can be converted into valuable electrical energy. In addition, research conducted by [3] found that biogas production from chicken manure can be increased by adding biochar, which helps increase the efficiency of anaerobic fermentation. Therefore, this study will conduct an in-depth analysis of the potential of laying hen manure as a source of electrical energy, starting from biogas production to conversion to electrical energy.

* Corresponding author: I Ketut Perdana Putra

This research aims to provide insight into the use of chicken manure as a sustainable alternative energy source and encourage the implementation of biogas technology in the livestock sector as a strategic step in reducing organic waste and increasing energy efficiency.

2. Literature review

Research on biomass power generation technology in chicken farms has also been conducted in Indonesia. One study shows that a thermoelectric generator can produce a voltage of up to 8 V with a temperature of around 42.8°C and a current of 31.5 mA when using chicken manure as fuel [4]. Research on using chicken manure as a renewable energy source has been conducted in various countries. In Israel, researchers have succeeded in developing a method to convert chicken manure into solid biomass fuel that can partially replace coal in power plants. This process involves heating chicken manure to 250°C under certain conditions, producing a material similar to coal. Replacing up to 10% of coal with this biomass can significantly reduce greenhouse gas emissions [5]

Research by Rahayu [6] developed chicken manure processing technology through an anaerobic process using the BIOKOYAM Reactor to produce household-scale energy. The results showed that on the 12th day of the process, the composition of the gas produced consisted of 78.26% methane (CH_4) and 21.74% carbon dioxide (CO2). Refer to Nasution and Handayani [7] discussed using poultry waste as renewable energy. This study emphasizes the importance of managing poultry waste to produce biogas that can be used as an energy source while reducing the environmental impact of livestock waste. Refer to [3] found that adding biochar or charcoal can improve the anaerobic decomposition and increase biogas production from chicken manure. This finding suggests that certain modifications in the biogas production process can increase the efficiency and energy output produced. Budiyono [8] in their study on the kinetics of biogas production from cow manure, found that the efficiency of biogas production can be increased by setting the optimal C/N ratio, which is also relevant in biogas production from chicken manure.

Refer to [9] studied the efficiency of biogas conversion into electrical energy, showing that the use of the right conversion system can increase the amount of energy produced from livestock waste. Research by [10] studied biogas production using a batch system using a mixture of chicken manure, cow manure, and mini elephant grass. The results showed that the mixture without chicken manure (treatments A and B) produced the highest biogas production, with a total production of 4,916 mL and 4,610 mL, respectively. The gas flame test showed that the biogas produced was good quality with a blue flame. This study indicates that selecting the right mixture of materials in biogas production can affect the Volume and quality of the biogas produced. Research conducted by [11] concluded that using waste as renewable energy is a technological advancement that needs to be improved and utilized optimally. In addition to reducing waste generation, renewable energy can also help humans find other energy sources and reduce the use of non-renewable energy. Banyuwangi Regency has the potential for waste to energy from livestock waste and organic waste produced. Bioenergy is produced from the processing of livestock waste and organic waste. The total bioenergy produced from livestock waste in Banyuwangi Regency reaches 297,681 m3. The total electrical energy produced from organic waste in Banyuwangi Regency reaches 414,061 kWh daily. Research on renewable energy must be continued to support waste reduction activities and the discovery of renewable energy, especially in Indonesia. These studies indicate that chicken manure has significant potential as a renewable energy source through biogas production. Implementing appropriate technology and effective management can increase the efficiency of energy production and provide sustainable solutions to livestock waste problems.

3. Research method

The steps taken in this study are as follows:

Field data collection in the form of the number of chickens in the research location. The results of interviews and observations in the field found that the number of laying hens in the research location was 2000.

In this study, data collection was carried out by calculating the number of chickens in 1 laying hen farm location. The data on the number of chickens is 2000. The average amount of chicken manure production per head per day can be calculated from the number of chickens. The biogas composition in chicken manure contains around 60-65% methane. The condition of laying hens and chickens manure looks on figure 1 and 2.

Figure 1 Condition of chicken manure piled up in the research location

Figure 2 Laying hen farms in the research location

4. Result and Discussion

4.1. Biogas Conversion Process to Electrical Energy

The anaerobic fermentation process is the first process of converting biogas to electrical energy. Anaerobic fermentation of chicken manure in a digester is a bioconversion process of organic matter in chicken manure into biogas through the activity of microorganisms without oxygen. This process produces methane gas (CH_4) and carbon dioxide (CO_2) as the main products, as well as residue in the form of digestate, which can be used as organic fertilizer.

Table 1 Data on the amount of animal manure production per day

Animale Type	Average weight (kg)	Manure Production (kg/ekor/hari)	Source
Laying hens	1.5 - 2.0	0.12 - 0.15	Nasution & Handayani (2017)
Broiler chickens	2.0 - 2.5	0.18 - 0.22	Ma et al. (2013)
Diary Cows	500 - 600	30 - 40	Budiyono et al. (2010)
Beef cattle	400 - 500	20 - 30	Agency for Renewable Energy (2019)
Goats / Sheep	30 - 40	2 - 4	Yasin et al. (2018)
Pigs	90 - 150	2.5 - 4	Sugeng Triyono (2020

The first stage in anaerobic fermentation is Hydrolysis, where microorganisms break down complex compounds in chicken manure, such as proteins, fats, and carbohydrates, into simple compounds such as amino acids, fatty acids, and sugars. After that, the acidogenesis process occurs, where simple compounds from Hydrolysis are converted into organic acids, alcohols, hydrogen (H_2), and carbon dioxide (CO_2). The third stage is the Acetogenesis process where organic acids formed in the previous stage are converted into acetic acid, hydrogen, and carbon dioxide. The last stage is the methanogenesis process, where methanogens (methanogenic bacteria) will convert acetic acid, hydrogen, and carbon dioxide into methane (CH_4) and carbon dioxide (CO_2), which are the main components of biogas.

Table 2 Biogas content composition

Element	Formula	Concentration(%)
Methane	CH4	50 - 75
Carbon dioxide	CO_2	25 - 45
Water vapor	H2O	2-7
Oxygen	O2	< 2
Nitrogen	N2	< 2
Hydrogen Sulfide	H2S	< 2
Ammonia	NH3	< 1
Hydrogen	H2	< 1

Research by [12] conducted the development of a biodigester in an anaerobic bioreactor with a capacity of 1,200 L. The parts of the bioreactor include a slurry input channel, a digester chamber, a gas output channel, and a drain channel for the remaining fermented slurry. A total of 603 kg of chicken manure in one fermentation process can produce 61.5 m3 of biogas. The biogas produced can then be used for heating the barn, cooking, and other energy conversion uses. Meanwhile [13] conducted a study examining biogas production from a mixture of cow dung and chicken manure with various ratios. The best results were obtained at a ratio of 1:1, producing a total biogas of 35,690 ml and a biogas productivity of 0.33 liters/g of organic material. Research conducted by [14] in his thesis examined biogas production from a mixture of water hyacinth and chicken manure. The results show that adding water hyacinth can affect the biogas formation process, with the accumulation of nitrogen and sulphide elements in chicken manure affecting the anaerobic process. Several factors affect fermentation, such as temperature, where the ideal temperature for fermentation is 35-40°C (mesophilic) or 50-55°C (thermophilic). At the same time, the optimal acidity value for fermentation is in the range of 6.5-7.5. The optimal carbon-to-nitrogen content (C : N ratio) is 20-30:1. The optimal humidity for microorganisms to ferment is 80-90%. At the same time, the time needed for fermentation chicken manure into biogas is around 15-30 days.

4.2. Volume of biogas produced from chicken manure.

Based on data on the number of chickens in the research location, which is 2000. Analysis of the Volume of chicken manure and biogas produced based on the following data:

- Number of chickens = 2000
- Manure production per chicken per day = 120 - 150 grams
- Total manure production per day = 2000 × (0.12 − 0.15) kg = 240 − 300 kg/day
- Biogas production from chicken manure = around 0.037 m^3 of biogas per kg of manure
- Total volume of biogas produced = (240 − 300) × 0.037 = 8.88 − 11.1 m^3/day

Table 3 Conversion of animal waste into biogas

Animale Type	Manure Production (kg/head/day)	Biogas Production(m^3/kg manure)	Total Biogas (m^3/head/day)	Reference
Cow	20	0,023 – 0,040	0,46 – 0,80	Tonglolangi
Buffalo	20	0,023 – 0,040	0,46 – 0,80	Tonglolangi

Pig	2,72	0,040 – 0,059	0,1088 – 0,1605	Maluaegha et.al. (2018)
Chicken	0,15	0,07	0,0105	Sanjaya (2015)

With this calculation, it can be concluded that with 2000 chickens, around 8.88 - 11.1 m^3 of biogas can be produced daily, which can be used as a source of electrical energy.

4.3. Efficiency of biogas conversion to electricity

Biogas produced from anaerobic fermentation can be converted into electrical energy using a biogas generator or micro gas turbine. The energy conversion efficiency from biogas to electricity depends on several factors, including the methane content in the biogas, the type and efficiency of the generator used, and the waste heat utilization system (CHP - Combined Heat and Power).

Biogas produced from chicken manure contains 60-65% methane (CH_4), while the rest consists of carbon dioxide (CO_2) and other gases. High methane content is very important because the calorific value of biogas depends on it, with an average calorific value of biogas around 20-25 MJ/m^3.

Biogas generators generally have an electricity conversion efficiency of around 30 - 40%, depending on the technology used. Most of the energy in biogas will be lost in heat, so the CHP (Combined Heat and Power) system can increase the total efficiency by up to 70 - 80% by utilizing waste heat.

Based on previous calculations, biogas production from 2000 chickens is around 8.88 - 11.1 m^3 daily.

If the calorific value of biogas is 20 MJ/m^3, then the total energy available per day is:

Ebiogas = amount of biogas production X calorific value of biogas

$$= (8.88 - 11.1) \times 20 \text{ MJ} = 177.6 - 222 \text{ MJ/day}$$

If using a biogas generator with an electrical conversion efficiency of 35%, then the electrical energy that can be produced is:

$$E \text{ electricity} = (177.6 - 222) \times 0.35 = 62.2 - 77.7 \text{ MJ/day}$$

If converted into kWh units, because 1 kWh = 3.6 MJ, then the estimated electrical energy that can be produced is:

The electrical power produced is:

$$Plistrik = (62.2 - 77.7) / 3.6 = 16 - 20 \text{ kWh/day}$$

To increase the efficient conversion of energy from biogas to electricity, several strategies can be applied:

- ·Using high-efficiency biogas generators (CHP technology).
- ·Optimizing the anaerobic fermentation process to produce biogas with higher methane content.
- ·Using a waste heat utilization system to increase total efficiency.
- ·Improving maintenance of biodigesters and generators to minimize energy loss.

5. Conclusion

Based on the results of the analysis above, the following conclusions can be drawn:

- Chicken manure has a high methane gas content, so it has excellent potential to be used as a biogas material. From 2000 chickens, around 240-300 kg of manure/day can be produced. Assuming that around 0.037 m^3 of biogas per kg of manure, the amount of biogas produced is 8.88 - 11.1 m^3/day. Moreover, if this value is converted into electrical energy assuming the calorific value of biogas is 20 MJ/m3. It can produce 16 - 20 kWh

per day if converted into electrical energy. This electrical power can be used as an alternative energy source for livestock purposes or local electricity needs.

- Biogas energy is cheap and environmentally friendly, but converting biogas into electricity, especially in an electric generator, requires a large investment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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