Original Research Article

KINETICS AND BENEFITS OF METHANOGENESIS OF POULTRY MANURE TO BIOGAS IN TERMS OF ENERGY AND EMISSIONS

Abstract

Biogas has the potential to lessen dependency on fossil fuels while simultaneously increasing access to energy in rural areas. This technique is highly important in rural regions, where energy crises are common. Biogas can be utilized in the home for cooking and heating, as well as converted into electricity for industrial usage. At Sriya Farm, Avalamarakalaghatta Village, Mulbagal Taluka, Kolar, this study was conducted to determine the viability of using poultry litter for biogas production and energy generation. The amount of waste generated by poultry farms was calculated, and technology for converting waste into biogas was addressed. Finally, the quantity of electricity produced from poultry waste was determined. Daily feeding of 5-6 tonnes of chicken litter resulted in the generation of 680 units of energy per day. From this, 50 kW biogas power was generated which is used for working for 10-12 hours per day. The adoption of this technology saves 113970 L of diesel per year and 78926 kg of equivalent LPG per year. The project costs Rs. 59.00 lakhs and has a payback period of 1.96 years, meeting all of the industry's energy needs.

Keywords: Poultry litter, Biogas, Electricity generation, Diesel, LPG and Payback period

1. INTRODUCTION

The concept of energy planning for a rural area by using locally available residues, like agricultural wastes to meet the energy demand towards the global population growth. Biogas production from these feedstocks are well-established technology for renewable energy generation and also organic material volarization(Scarlat et al., 2018). Biogas is the final product of the so, called anaerobic digestion process, in which various metabolic activities have been carried out by the different microorganisms for organic matter decomposition (Kumar et al., 2022). This process is practices from the ancient days for providing heat and power for domestic households. Now a days the biogas energy generation sector growing rapidly and creating novel technologies for the construction of advanced bioenergy factories (Rafiee et al., 2021). The experiment's main goal is to acquire a sustainable usage of poultry waste to produce biogas with rich methane content. The resulting slurry can be utilized in green farming. In India, there is a lot of poultry farming which produces poultry litter and dropping waste (Chatterjee and Rajkumar, 2015). This waste contains hazardous gases like ammonia (NH_3) and Sulphur compound, which causes water and air borne diseases. The sole purpose of this project is to transform poultry waste into a long-term fuel source (Gohil et al., 2021). Biogas, among other renewable energy sources is an environment friendly and practical option for long-term power generation. Biogas is produced through the bio-methanation of biodegradable waste and nutrient-rich materials which produces a considerable amount of biogas during anaerobic digestion. The degradation of natural materials by microorganisms that do not have access to oxygen is known as bio-methanation. It is a natural process in which natural carbon is converted to carbon dioxide and methane in a multi-step process. Biogas can be made from a variety of materials, including animal compost (cowdung, poultry etc.,), energy crops (rice hulls, wheat hulls etc.,) and other wastes (Nwankwo, 2014). In a biogas setup, anaerobic reactions are common, with methanogenic reactions supporting waste substrate derived from poultry and animal waste (Heng, 2017). The biogas produces consists of 50-70% methane, 30-40% carbon dioxide, 5-10% hydrogen and 1-2% nitrogen and traces of water vapour and hydrogen sulphide (Barik and Murugan, 2015). Hence, the objective of the study is to utilize the biogas technology to overcome the problem of poultry waste management intern to achieve the self-sufficiency in power generation by reducing the carbon emission to the atmosphere.

MATERIALS AND METHODS

2.1. Location of the study

In this study, Sriya Farm, Avalamarakalaghatta Village, Mulbagal Taluka, Kolar District (Fig.1) was selected for 50 kW capacity/day biogas power plant installed for the generation of electricity utilizing poultry litter wasteunder central financial assistance from Ministry of New and Renewable Energy (MNRE)- Govt. of India.

2.2. Physico-chemical properties of poultry droppings

The poultry litter waste sample was collected from the selected industry and stored at a room temperature before characterization. The pH, total solids (TS), volatile solids (VS), total kjeldahl nitrogen (TKN) and chemical oxygen demand (COD) were determined as per the standard procedures of American Public Health Association for water and wastewater (Federation and Association, 2005) and total organic carbon (TOC) is determined using (Mylavarapu, 2014).

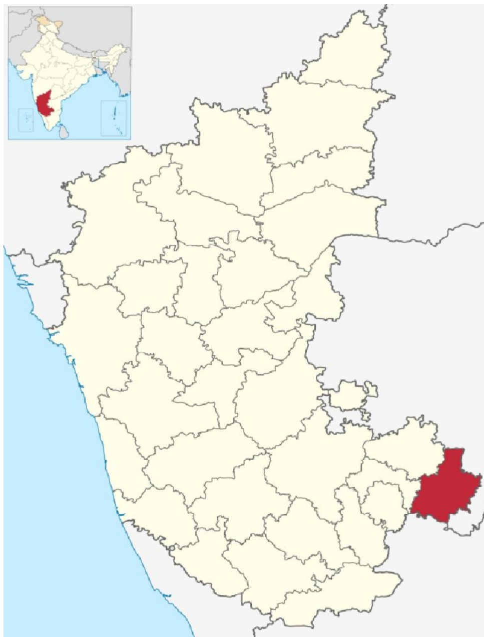

Fig1. Location of the study

2.3. Design of Experiment

The amount of organic industrial waste produced is determined by a variety of factors, including eating habits, living standards, the extent of economic activity, and the seasons. Data on quantity variation and generation can help with collection and disposal system planning. Under the financial help of MNRE, a 500 m^3 biogas plant was built with daily feeding of 5-6 tonnes of chicken waste using UASB technology at the chosen location for the generation of 50 kW electrical energy. The biogas is collected, cleansed, and fed into a generator, which generates energy. Sriya Farm, Kolar utilizing the biogas for borewell water pumping, feeding unit, grinder and chaff cutter operation, processing equipment, and captive use they use the generated electricity for 10-12 hours per day. The completed process chart of the project was shown in the Fig. 2 and the process flow chart of the poultry litter treatment was shown in the Fig. 3.

2.4. Kinetic model study

Kinetic analysis is a widely used concept for identifying the significance of inter-variable interactions in order to guide experimental design, evaluate experimental results and describe particular system performance. Experimental kinetic studies can be used to stimulate digester behaviour and forecast biogas output of a running plant under similar conditions. To forecast biogas output and evaluate kinetic parameters, a first order model and modified gompertz models were used in this work.

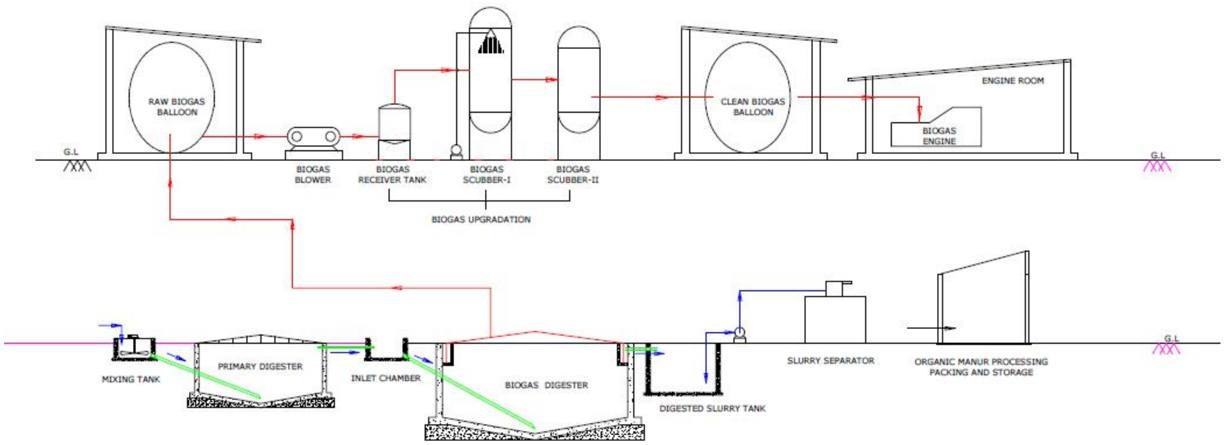

Fig.2: Setup of the 500 m^3 biogas plant at Sriya Farm

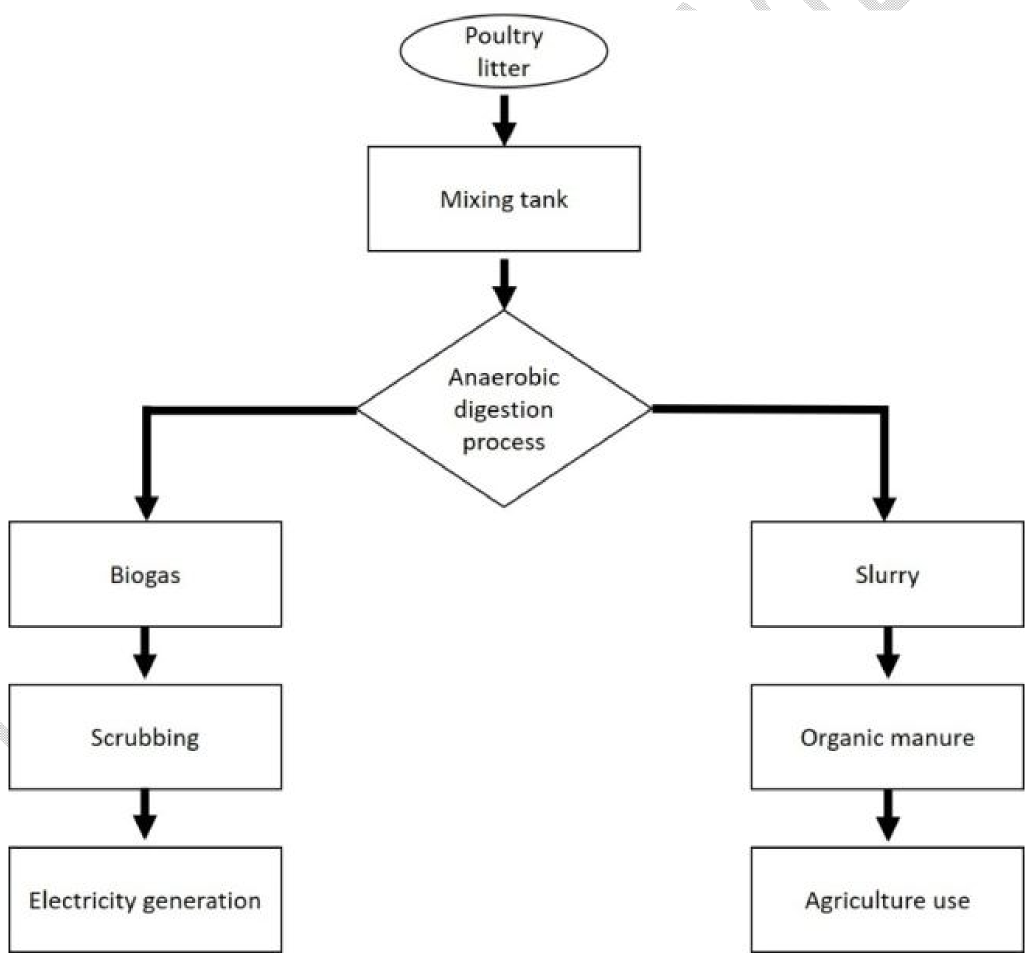

Fig.3: Flow chart showing the treatment of poultry litter.

2.4.1. First order kinetic model

The biogas yield production is predicted using the first order kinetics equation (Budiyono et al., 2014 & Lafratta et al., 2021).

$$P = Po * (1 - EXP(-k * t)) \dots \dots \dots \dots (1)$$

The cumulative biogas production is P, the ultimate biogas yield is Po, the first order rate constant is k, and the time is t. To determine the rate of reaction, first order kinetics employed empirical linear regression, with the value of the slope of the linear plot representing the supplied substrate properties (Angelidaki et al., 2009). However, the linear form of the first order model, which is an exponential form, cannot be utilized to account for and predict cumulative biogas generation throughout the process, especially beyond the exponential phase (Li et al., 2011).

2.4.2. Modified Gompertz model

The Modified Gompertz model is a non-linear kinetic model that is used to determine the length of the lag phase and the rate at which biogas is produced.

$$P = Po * EXP\left(-EXP\left(\left(\frac{R * 2.7183}{Po}\right) * (L - t) + 1\right)\right) \dots \dots \dots \dots (2)$$

In the following equation L is the lag phase duration, R is the biogas production rate and P_o is the biogas potential at time. The standard statistical metric used to study the model performance (Lahbab et al., 2021).

RESULTS AND DISCUSSION

3.1. Physico-chemical properties of poultry litter

The poultry droppingsare selected as feedstock and the characterization of the feedstock was done as per the standard procedures and the results were mentioned in the Table.1.

Table.1: Physico-chemical properties of poultry litter

Parameter	Fleshings
pH	7.6-7.9
Total solids (%)	78.2±0.24
Volatile solids (%)	65.6±0.29
Chemical Oxygen Demand (g/g)	1.13±0.02
Total Organic Carbon (g/kg)	39.8±0.31
Total Kjeldahl Nitrogen (g/kg)	9.62±0.17
C:N ratio	4.13

3.2. Working of the biogas plant

Installed biogas plant generates about maximum of 680 electrical units per day and 62.50 HP biogas generator runs for 10-12 hours/day. The generated energy is equivalent to the 215 kg of LPG per day also yielding with 3 tonnes/day of organic manure. The details of the work shown in the Table 2.

Table 2: Particulars of biogas plant installed

Design capacity	500m^3 biogas/day
Feed material	Poultry litter
Electricity generation	620-680 electrical units/day runs for 10-12 hrs
Energy yield	Equivalent to 215 kg LPG/day
Organic manure	3 tonnes/day
Total project cost	Rs. 54.50 lakhs

3.3. Daily biogas production

The biogas production was measured using the developed setup shown in the Fig.1 and the cumulative biogas production values are shown in the Fig.4. the comparison of monthly biogas production data and cumulative biogas production availed from the setup was shown in Fig.4. It is observed that, with a daily input of 3 tonnes of organic waste 500 m^3 of biogas was produced with a monthly biogas production in the range of 13000 to 19000 m^3. Whereas the cumulative biogas production was found to be around 55000 m^3 at the end of 33 months.

3.4. kinetic model studies

Kinetic study for the cumulative biogas production from the biogas plant was carried out using the first order kinetics and modified gompertz model. Kinetic constants of models were determined by using non-linear regression. The results obtained from kinetic studies were given in the Table 3 and Table 4 respectively. The comparison of the experimental and the predicted values of cumulative biogas production were shown in the Fig.5 and Fig.6.

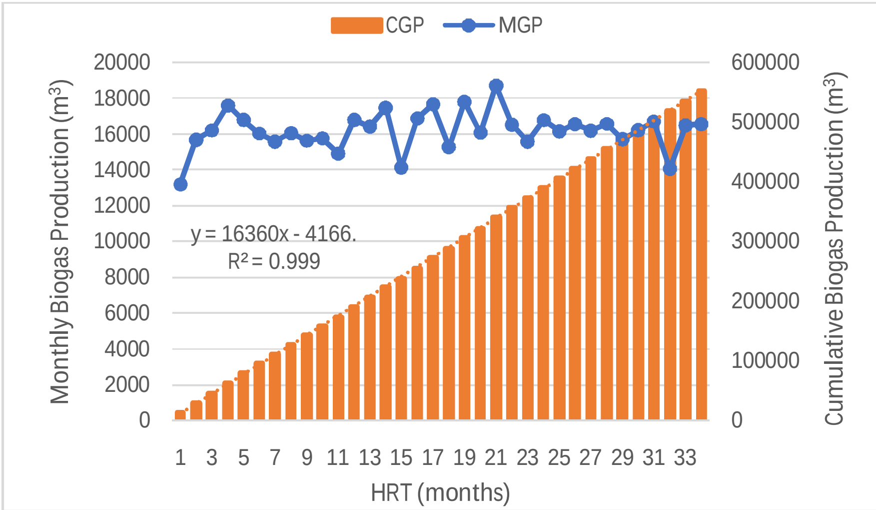

Fig.4: Cumulative biogas production from poultry litter

Table 3: Results of kinetic study – first order kinetic model

Kinetic model	First order kinetics
C- Actual	551148.0
C- Predicted	548482.9
k	0.073
R^2	0.9837

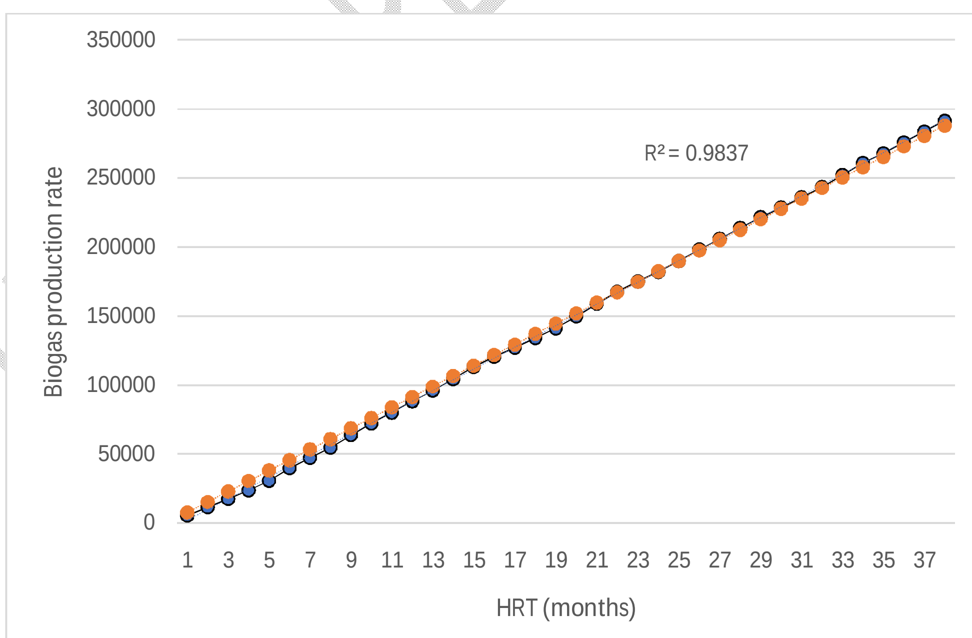

Fig.5: Comparison of experimental data and the first order kinetic model predicted values.

Table 4: Results of kinetic study – modified gompertz kinetic model

Kinetic model	Modified gompertz model
C- experimental	551148.0
C- predicted	549815.4
R	297.70
L	1.97
R^2	0.9998

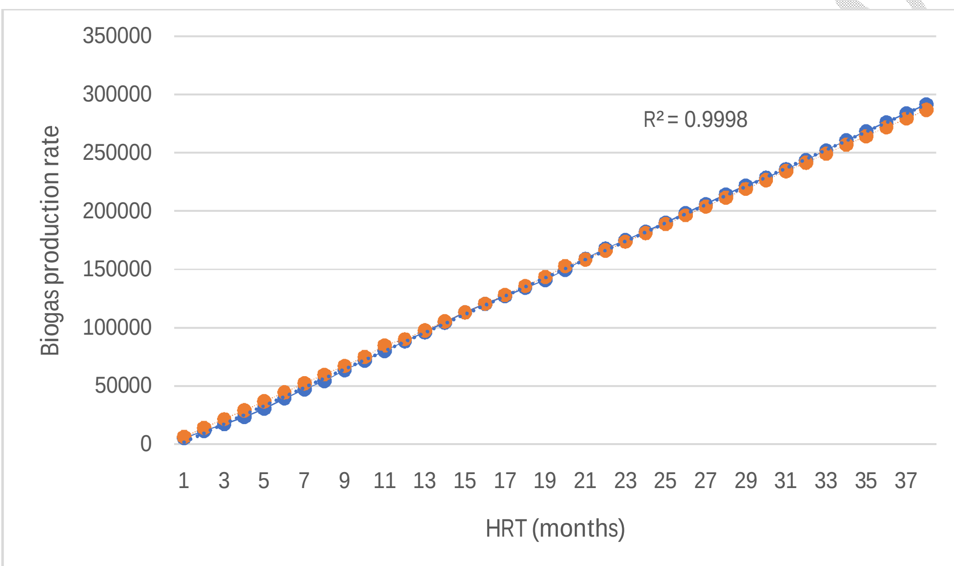

Fig.6: Comparison of experimental data and the modified gompertz model predicted values.

From the above kinetic models, shows that the experimental biogas yield from the biogas plant is 551148.0 m^3. The predicted biogas yield based on first order kinetics was548482.9 m^3 with a rate constant of 0.073 and the biogas yield from modified gompertz model was 549815.4 m^3 with a production rate of 297.70 m^3/day with a lag phase of 1.97. based on the results obtained from these models modified gompertz model is best suitable for this study than the first order kinetic model. The similar results were recommended by Angelidaki et al. (2009) on the modelling of biomethanation technology for organic waste decomposition.

3.5. Environment Impact of the Project

Biogas systems have two main impacts in terms of greenhouse gas emissions. To begin with, biogas is 21 times more effective than CO_2 at reducing methane emissions caused by animal waste storage. Second, turning biogas to energy reduces the amount of CO_2 emitted by fossil fuels. The environment impact of biogas was given in the Table 5.

3.6. Cost economics of the study

In the case of biogas plants, a detailed cost economics was elaborated to analyze the payback period of the biogas generation plant. The complete details of the cost shown in Table 6.

Table 5: Environment impact of the biogas technology

Annual greenhouse gas (GHG) emission reduction of CO_2 (tons/year)	2600
Saving of firewood (tons/year)	658
Generation of electricity (units/day)	680
Generation of organic-manure (tons/year)	3246
Saving of forest (ha/year)	5
Annual saving of trees (Nos)	976
Total kg of CO_2 absorb/year	19864
Replacement of diesel (ltr/year)	113970
Replacement of LPG (kg/year)	78962

Table.6: Cost economics of the biogas generation plant

	1-year	**3-years**
A) **Revenue generation**		
Cost of electricity @ Rs. 7.00/kWh (7×680×30 days)	17,13,600.00	51,40,800.00
Cost of organic manure @ Rs.2000/ton (3t×2000×30 days)	21,60,000.00	64,80,000.00
Total cost	38,73,600.00	1,16,20,800.00
B) **Operation and maintenance cost**		
Cost of organic waste @ Rs.0.5/kg (0.5×5000×30 days)	9,00,000.00	27,00,000.00
Cost of labour @ Rs. 6000/month	72,000.00	2,16,000.00
C) Auxiliary consumption	18,000.00	54,000.00
Total	9,90,000.00	29,70,000.00
Payback period (years)	1.96	

4. CONCLUSION

The benefits of biogas power generation from the poultry waste was generated 680 units of electricity to run a 50 kW biogas power generator for 10-12 hours. The biogas power generations are independence from the irregular and costlier state grid power, ensure continuity of electricity due to self-efficiency in power generation. The results of the kinetic study revealed that the predicted biogas yield based on first order kinetics was 548482.9 m^3 with a rate constant of 0.073 and the biogas yield from modified gompertz model was 549815.4 m^3 with a lag phase of 1.97 against the experimental value of 551148.0 m^3. Based on these results, modified gompertz model is best suitable for this study than the first order kinetic model. This technology is environment friendly and also ensure for good quality organic manure. The cost of the project is Rs. 59.00 lakhs and payback period was about 1.96 years.

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