Scientific and technical basis for biogas production and utilization in Turkmenistan

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Abstract. This study demonstrates the feasibility of biogas production from poultry litter. Based on this research a biogas plant (digester) with a volume of 2 m^3 was designed, constructed, and operated, as a result of digestion in 20 days, biogas with the content of methane (CH_4) 65.77% was obtained. The study also calculated biogas production in a thermophilic and mesophilic mode for 20 days in June and July to assess the energy supply of the "Kekech" poultry farm with 45,000 chickens. The results of the research showed that in thermophile mode in May month on average per day, it is possible to receive 167200 m^3 of biogas, and in mesophile mode 162954 m^3, and for July month for thermophile mode 158554 m^3/day, and in mesophile mode 165000 m^3/day.

1 Introduction

Fossil fuels, especially natural gas are currently the main source of energy in all power plants of Turkmenistan [1], and in general, in countries with rich resources of fossil fuels Taking into account the growth rate of electricity generation [2] and the levels of greenhouse gas emissions, and the implementation of the Paris Agreement, it is necessary to find an alternative method or a more harmless method of generating electricity and heat. As scientific advances in this field show, the way out is the use of renewable energy sources (RES) such as solar, wind, geothermal, and biogas [3-4].

Turkmenistan is both an agrarian and energy-developing country and the climate is sharply continental [5].

This in turn allows the development of agriculture and livestock and poultry complex.

Furthermore the above-mentioned it can be concluded that Turkmenistan has a huge potential for the production and use of biogas in various sectors of the economy.

Aim:

- Investigate the potential of biogas production (by their anaerobic fermentation) and the content of biogas produced from poultry litter.
- Estimate the amount of biogas production depending on the number of chickens in the poultry farm "Kekech".
- Analyze the impact of digestion methods (thermophilic vs. mesophilic) on biogas yield in May and July, considering ambient temperature.

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The object of the study is the projected methane tank volume of 2m^3 and the amount of urine produced by chickens on the "Kekech" farm.

2 Materials and methods

2.1 Biogas composition, global trend of production technology, and comparative characteristics

Biogas is a mixture of gases. Its main part is methane (CH_4) - 55-70%; carbon dioxide (CO_2) – 28-43%; small amounts of other gases are also present, such as hydrogen sulfide (H_2S). On average, 1 kg of organic matter in anaerobic digestion leaves 0.18 kg of methane, 0.32 kg of carbon dioxide, 0.3 kg of water, and 0.3 kg of undissolved waste [6].

Biogas is close to natural gas in terms of its physical and chemical parameters, as its main component is methane. Sources of biomethane production are products of methane fermentation of organic substances of plant and animal origin.

It should also be noted that the higher the temperature, the faster chemical reactions take place. This also applies to the processes of biological decomposition. Microorganisms involved in biogas synthesis can be divided into three groups: psychro-, meso- and thermophiles [7]. The biogas produced can be converted into energy in several ways. The predominant use is combined heat and power (CHP) production in a gas engine installed at the site of biogas production.

There are mainly two reasons for this:

Firstly, biogas production is an almost continuous process; it is quite difficult or, in the short term, even impossible to control the operation of anaerobic digesters according to any given demand profile. Figure 1 shows the growth in installed capacity of biogas plants globally from 2013 to 2022.

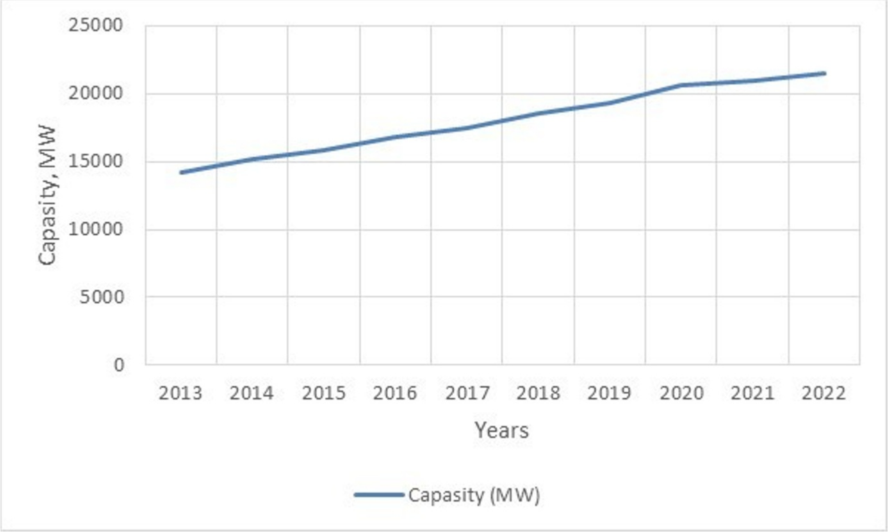


Fig. 1. Growth of installed capacity of biogas plants in the world.

Secondly, the promotion of renewable energy is centered on power generation. Figure 2 shows the growth of energy production from biogas in the world from 2013 to 2021 [8].

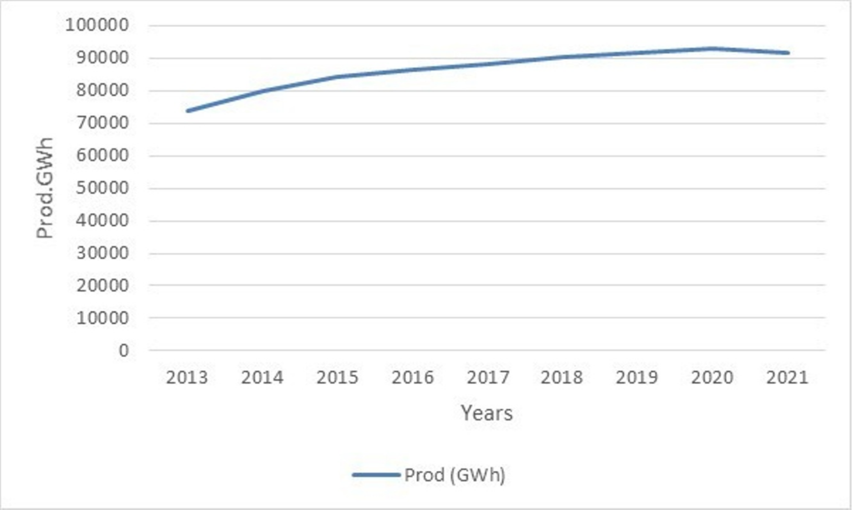


Fig. 2. Growth of energy production from biogas in the world.

Today, due to the growing use of biogas, the demand is increasing, because the production allows to use of local resources (which are rubbish and pollute the environment) to produce biogas, which has the same properties as natural gas, while the price of natural gas is increasing every year. The use of biogas is an excellent tool for those countries where there is very little sun, wind, and places for the construction of photovoltaic solar plants, and some of the distinctive characteristics of energy carriers are presented in Table 1. From a technical point of view, it can be concluded that biogas production, and as the latest technology for the utilization of RES and energy-efficient technologies [9].

Table 1. Comparison of various fuels.

Fuel	Calorific value, (kcal)	Burning mode	Thermal efficiency, (%)
Electricity, kWh	880	Hot plate	70
Coal gas, kg	4004	Standard burner	60
Biogas, m3	5373	Standard burner	60
Kerosene, l	9122	Pressure stove	50
Charcoal, kg	6930	Open stove	28
Soft coke, kg	6292	Open stove	28
Firewood, kg	3821	Open stove	17
Cow dung, kg	2092	Open stove	11

2.2 Formula for calculation

The volume of the digester tank is determined using the following expression:

$$V_m = m_{og} \cdot t_{tur} \cdot \nu \quad (1)$$

Where: m_{og} - the output of the dry poultry litter per day, kg; t_{ox} - poultry litter accumulation time, oxidation period in the digester (from 8 to 20 days), day; ν - specific weight of a liquid mass of 1 kg dry poultry litter, (0.02 m^3/kg).

The daily yield of dry poultry litter is determined by the following expression:

$$m_{og}=m_{day}\cdot(1-\omega) \quad (2)$$

Where m_{day}- 1250 kg/day; ω -initial humidity (about 75%) daily output of the poultry litter kg/day [10].

The daily output of biogas is determined using the following expression:

$$B_b=m_{og}\cdot b \quad (3)$$

Where b -the yield of biogas when 1 kg is processed (from 0.2 to 0.4 m^3/kg);

The total thermal energy obtained from biogas is determined using the following expression:

$$Q_{total}= B_b\cdot Q_b \quad (4)$$

Where Q_b=20-25 MJ/m^3- heat of combustion of biogas.

The heat consumption to heat the liquid mass in the digester from t_1=15°C to t_2=35°C is determined using the following expression:

$$Q_{low}=\frac{c_g . m_{0day}\cdot\upsilon\cdot\rho_d(t_2-t_1)}{\eta} \quad (5)$$

Where c_g- the thermal density of liquid mass (c_g=0.00406MJ/kg·°C); η- efficiency factor of heating unit (η=0.7).

Heat consumption for private needs is determined using the following expression:

$$Q_{pn}=1.06Q_{low} \quad (6)$$

Where 1.06 is the heat loss coefficient.

The total amount of biogas going to self-needs is determined using the following expression:

$$B_{pn}=\frac{Q_{pn}}{Q_b} \quad (7)$$

Product biogas output is determined using the following expression:

$$B_{p.b}=B_b-B_{pn} \quad (8)$$

3 Problem Statement

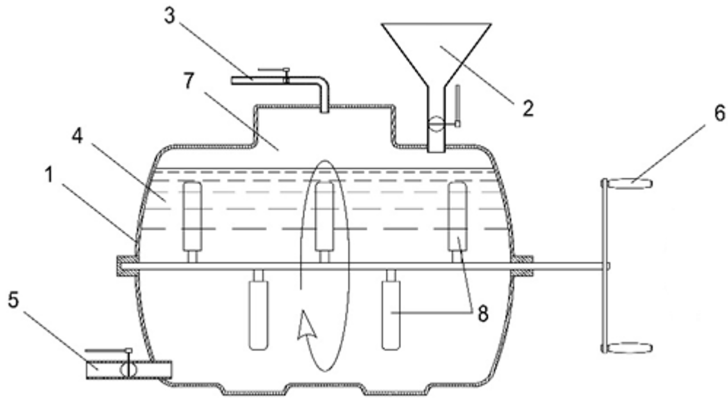
3.1 Study of the potential for producing biogas (during their anaerobic fermentation) and the content of the resulting biogas from poultry litter (chickens)

3.1.1 Experimental Design

Taking into account the advantages of obtaining biogas by using renewable energy sources, the experiment was conducted at the scientific-productional center "Renewable Energy

Sources" of the State Energy Institute of Turkmenistan. A small-scale biogas plant with a capacity of 2m³ was employed for the anaerobic digestion process (Figure 3).

A mixture of 60 kg poultry litter and 150 liters of water was loaded into the biogas plant. The digester content was agitated every 4 hours, with ambient temperature monitored. Biogas production commenced within 4-5 days, influenced by temperature.



1 – bioreactor; 2 – funnel; 3 – gas outlet; 4- biosolution; 5 – Digestate Outlet; 6 – manual agitator; 7 – biogas collection point; 8 – mixing impellers.

Fig. 3. Diagram of biogas structure.

The produced biogas was tested in the laboratory of the "Maryazot" production association. Its composition is shown in Table 2.

Table 2. Composition of the obtained biogas.

Argon	Nitrogen	Hydrogen	Methane
0.18%	24.75%	9.3%	65.77%

3.2 Study of the amount of biogas production depending on the amount of dust in the poultry farm "Kekech"

3.2.1 To study the poultry farm and the amount of litter produced in them

This section investigates the potential for biogas production from the poultry litter generated at the "Kekech" poultry meat and egg production complex located in the Mary district of Mary province [11]. The complex has a production target of 5 million eggs and 500 tons of poultry meat annually.

The "Kekech" complex encompasses 100 hectares dedicated to long-term fodder crop cultivation. The remaining 10 hectares house the main facilities, including five poultry houses. These houses are equipped with automated systems for lighting, air conditioning/heating, water purification, and feed distribution. Two laying hen houses each accommodate 48,000 birds, while the remaining three houses are broiler chicken houses, each with a capacity of 45000 birds. In total, the farm has a capacity of over 231000 chickens. An analysis estimates that each chicken produces approximately 0.178 kg (or 178 grams) of litter per day, translating to 65 kg per year.

Presently, the "Kekech" complex houses 45000 chickens and yields a daily meat production of 5 tons. The average monthly electricity consumption is 40000 kWh, and natural gas consumption is 45 m^3.

3.2.2 Biogas and methane yield estimation based on poultry litter input

This section presents calculations for estimating the theoretical biogas and methane production based on the amount of poultry litter generated at the farm. The results of these calculations are summarized in Table 3.

Table 3. Calculation results.

No.	Description	Unit	Value
1.	Volume of digester	V_m, m^3	500
2.	The daily output of dry poultry litter	m_{og}, kg/day	1250
3.	Daily biogas production	B_b, m^3/day	375
4.	Heat consumption to heat the liquid mass in the digester to +20 °C	Q_{low}, MJ/day	2320
5.	Consumption of heat for self-needs	B_{pn}, m^3/day	98.4

3.2.3 Study of the amount of biogas under various fermentation methods in May and July, depending on the ambient temperature in the poultry farm

According to [12], the most optimal temperatures for producing biogas are from +32 °C to +42 °C for mesophiles and +40 +80 °C for thermophiles, for this reason, in a scientific work to study the amount of biogas produced by various fermentation methods, measuring the ambient temperature were carried out in June and July for the first 20 days using a Fluke 971 digital temperature and humidity meter, the technical characteristics of which are given in [13], and the ambient temperature levels are shown in Figures 4-5.

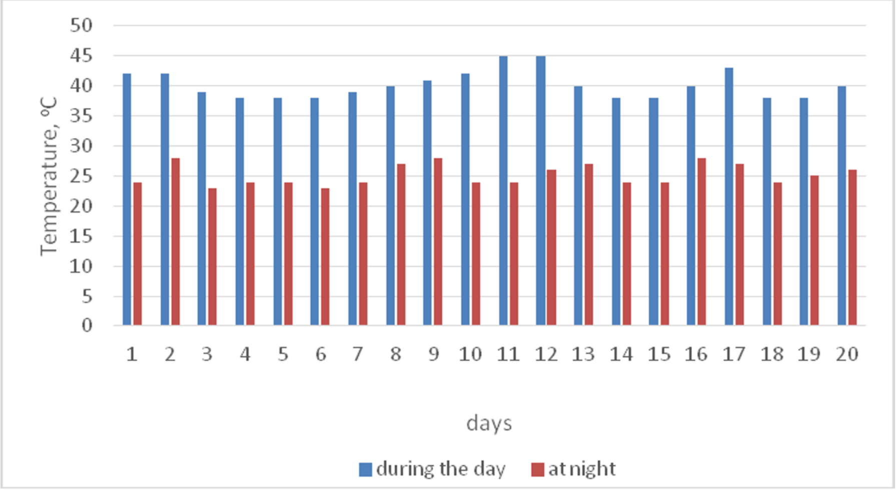


Fig. 4. Graph of the average ambient temperature by day in May in the city of Mary.

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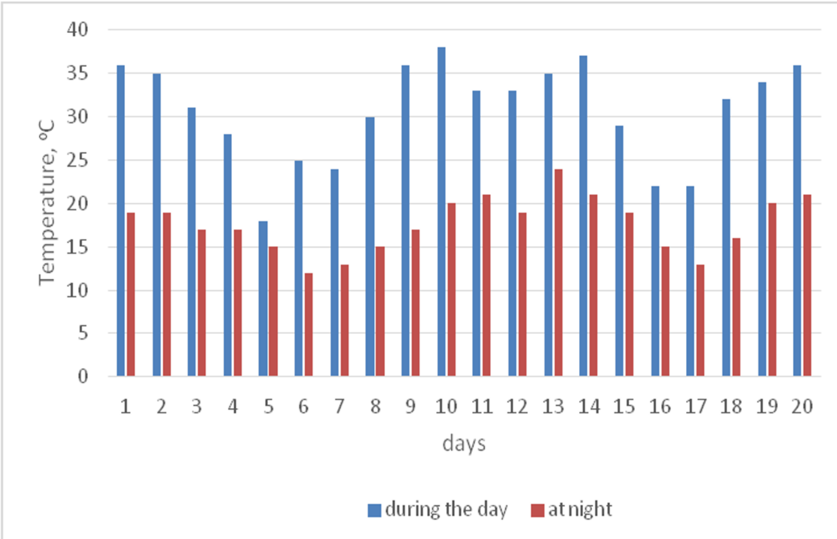

Fig. 5. Graph of the average ambient temperature by day in July in the city of Mary.

4 Results and Discussion

As can be seen from Figure 6, from the 1250 kg of poultry litter received in May, in 20 days, 7407 m^3 of biogas can be obtained in mesophile mode, and 7600 m^3 in thermophile mode;

As can be seen from Figure 7, from the 1250 kg of poultry manure received in July in 20 days, 7500 m^3 of biogas can be obtained in mesophile mode, and 7207 m3 of biogas in thermophile mode.

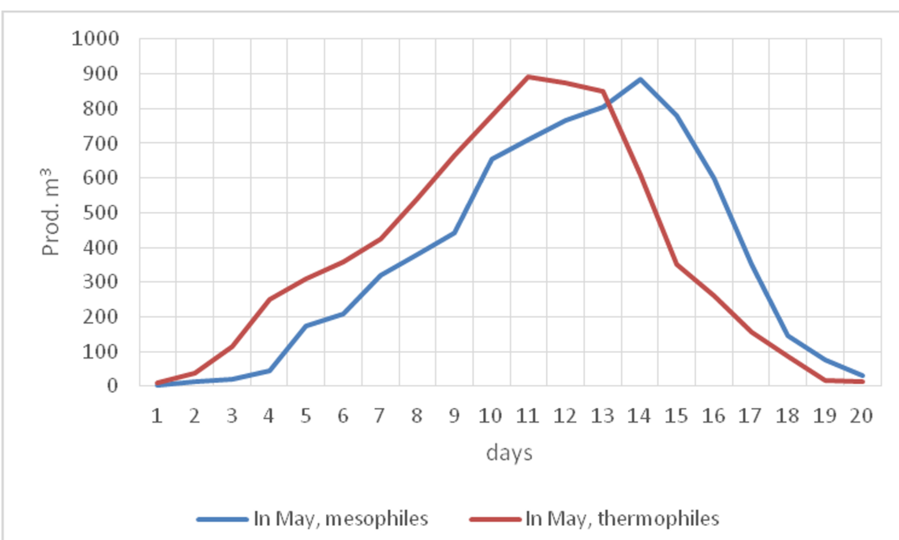

Fig. 6. Graph of productivity in May for thermophile and mesophile modes.

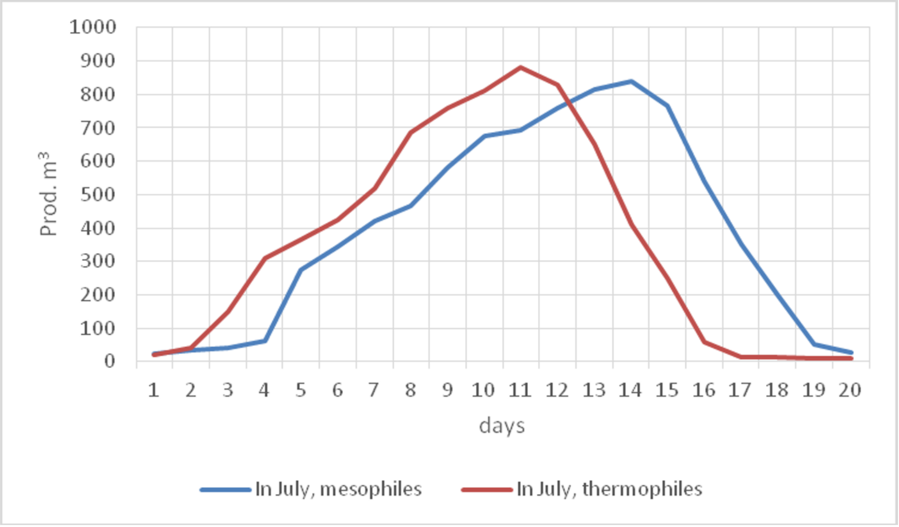

Fig. 7. Graph of productivity in July for thermophile and mesophile modes.

5 Conclusion

As a result of the research, the following results were revealed:

- When using poultry litter to produce biogas, the methane content was 65.77%.
- From 45000 chickens we get 1250 kg of poultry litter per day.
- From the obtained biogas in May, you can get an average of 167200 MJ of energy per day, which in turn will allow you to save money 4709.86 m3 of natural gas.
- From the obtained biogas in July, you can get an average of 165000 MJ of energy per day, which in turn will allow you to save money 4647.89 m3 of natural gas.
- Also, as can be seen from Figures 6 and 7, for the optimal mode of biogas production, thermophiles are suitable for May, and mesophiles are suitable for July.

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