Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM
ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Production of Biogas From a Mixture of Chicken Litter and Cow Manure and Its Effect on the Resulting Volume and C/N Ratio

Hendry Sakke Tira*, Rudy Sutanto

Mechanical Engineering Department, University of Mataram, Mataram, Indonesia
*E-mail: hendrytira@unram.ac.id

Received: April 28, 2023. Accepted: November 29, 2023. Published: January 20, 2024

Abstract: The livestock sector's waste is a potential raw material for producing biogas because it is abundantly available. This experiment aimed to understand the potential of two types of livestock waste to produce biogas. The two sources of raw material were mixed with different variations. The results showed that the volume of fermentation gas produced from livestock waste varied depending on the type and composition of the raw material used. Mixing was done to determine the best variation in producing biogas from chicken litter and cow manure. The volume ratio of litter to cow manure used was (0%:100%), (25%:75%), (50%:50%), (75%:25%), (and 100%:0%), with a total volume of 2 liters. In addition, 10% of EM-4 (effective microorganism) was added to the mixture of livestock waste that had previously been given 2 liters of water. The waste mixture was then fermented for 30 days. The fermentation process was carried out under mesophilic conditions at room temperature and pressure. This study showed that the higher the concentration of chicken litter in the mixture, the higher the carbon-to-nitrogen (C/N) ratio value. On the other hand, if there is a higher composition of cow manure in the mixture, the substrate pH value will be higher. Furthermore, a 50%:50% composition of chicken litter and cow manure produced a high volume of biogas. Similarly, the biogas formation rate in this composition showed the best performance. These results prove that the balance of carbon and nitrogen composition, temperature, and substrate acidity significantly affect biogas production.

Keywords: Biogas; Chicken Litter; Cow Manure; C/N Ratio.

Introduction

Ensuring equitable energy availability is a problem that needs to be solved. This is necessary to prevent a wide price disparity between regions. The depletion of energy resources, particularly fossil fuels, due to increasing market demand has led to efforts to find alternative fuel sources [1].

One alternative to solve the above problem is utilizing resources that have not been maximally managed, especially those generated from the livestock sector. The availability of livestock waste in Indonesia is a potential resource for producing renewable alternative energy, such as biogas.

Biogas is energy used as fuel from various waste materials and byproducts, such as organic waste and animal manure. Generally, biogas consists of 49% methane gas (CH_4), 45% carbon dioxide (CO_2), 1-5% hydrogen (H_2), 0.1-0.5% oxygen (O_2), 0-3% hydrogen sulfide (H_2S), and other impurities [2].

Some interesting things about biogas are that the raw material source is abundant and easy to obtain. However, biogas production is highly dependent on the biochemical properties of the raw material. The differences in the properties and characteristics of the raw materials greatly affect the growth of anaerobic bacteria in the digester [3]. The differences in the source of raw materials will also affect other things, such as the concentration of carbon and nitrogen (C/N ratio), acidity level, and temperature inside the digester. These factors greatly affect the volume of biogas produced [4].

Research has shown that various types of waste can be used as raw materials for biogas production, individually or in combinations of more than one type of waste. A previous work discussed increasing biogas production by mixing organic fractions of municipal solid waste with agricultural waste [5]. This research was conducted by testing the effect of adding various types of agricultural waste, such as straw, vegetable waste, and fruit peel waste, to the organic fraction of municipal solid waste (OFMSW) in an anaerobic reactor for 60 days. The research showed that adding agricultural waste can be a promising alternative to increase biogas production from organic waste.

Furthermore, the availability of nutrients and micronutrients is crucial in supporting the growth and activities of anaerobic microorganisms responsible for biogas formation. The main challenges related to the availability of nutrients and micronutrients may include the variability in raw material composition. Raw materials used for biogas production often have varying nutrient compositions. Some organic waste or animal manure types may lack the essential nutrients microorganisms need. Therefore, formulating a mixture of raw materials with a balanced nutrient content becomes challenging, especially in agricultural or livestock waste that may exhibit high variations [6].

Another thing that needs to be considered in producing high biogas is nutrient requirements for

How to Cite:
Tira, H., & Sutanto, R. (2024). Production of Biogas From a Mixture of Chicken Litter and Cow Manure and Its Effect on the Resulting Volume and C/N Ratio. *Jurnal Pijar Mipa*, *19*(1), 107–112. https://doi.org/10.29303/jpm.v19i1.4942

microorganisms. Anaerobic microorganisms require specific nutrients to sustain their metabolic activities. Essential nutrients such as nitrogen, phosphorus, and potassium are needed in adequate amounts. Nutrient deficiencies can inhibit the growth and reproduction of microorganisms, reducing the efficiency of converting raw materials into biogas [7].

A deep understanding of microorganism nutrient requirements, analysis of raw material quality, and the development of suitable mixture formulations are key to overcoming these challenges. Additional strategies may involve using organic fertilizers or adding external nutrients into digesters to ensure an adequate nutrient supply and maintain the necessary nutrient balance for microorganisms in biogas production [8].

Another work discussed improving the anaerobic digestion performance of corn silage, pig manure, and wheat straw by inoculating waste-activated sludge. The research showed that inoculation with waste-activated sludge can improve the anaerobic digestion performance of the mixture and can be a promising strategy to increase biogas production and potential recovery in the anaerobic digestion system [9].

Biogas production from chicken litter and its impact on organic matter degradation and nutrient release have also been conducted [10]. The results showed that using biogas from chicken litter in energy production can reduce the amount of agricultural waste disposed of and increase plant nutrient availability.

Based on previous research, mixing two different sources has the potential to produce a large volume of biogas. Two livestock wastes that can be used as raw materials for biogas production are cattle manure and litter waste. This research will investigate the variation of concentrations of these two raw materials on the volume of gas produced and their C/N ratio.

Research Methods

The raw materials used for biogas production are chicken litter waste, cow dung mixed with water, and effective microorganisms (EM-4). The volume of EM-4 added to each digester is 10% of the volume of water. The total volume of cow dung and litter waste is 2 liters, and the total volume of water and EM-4 is also 2 liters. Therefore, the ratio of raw materials and liquids used is 1:1. This result aligns with previous research that found this ratio to be the best for producing biogas [11].

The digester used for substrate fermentation has a volume of 6 liters. The digester is then isolated using soil with a thickness of 5cm. The soil is wrapped in a 50 kg bag to maintain a constant digester temperature. The experiment is carried out under environmental temperature and pressure conditions. Therefore, the fermentation process applied is mesophilic. Furthermore, the substrate fermentation is carried out for 30 days.

The study used five different mixtures or samples:
G1: 100% litter (2 liters) and 0% cow dung.
G2: 75% litter (1.5 liters) and 25% cow dung (0.5 liters).
G3: 50% litter (1 liter) and 50% cow dung (1 liter).
G4: 25% litter (0.5 liters) and 75% cow dung (1.5 liters).
G5: 0% litter and 100% cow dung (2 liters).

The observations performed in this study are:

Measurement of C/N ratio

The C/N ratio is measured using the Walkey and Black method to determine its carbon content. Nitrogen is measured using the Kjeldahl method. After determining the carbon and nitrogen content, each ratio is calculated to determine its C/N value.

Measurement of pH (acidity level)

After the substrate is ready for fermentation, the pH of the substrate before and after fermentation for 30 days is measured using a pH meter.

Digester temperature observation

Temperature observations are made after three days of fermentation. The temperature of the material in the digester is always measured with a thermocouple at the same time to avoid large temperature differences on measurement day. Temperature measurements are then taken every three days.

Gas pressure measurement

This observation is made after three days of fermentation with a measurement interval of 3 days. The measurement is made by observing changes in the height of the manometer U. Calculations are then performed to determine the biogas pressure every three days. The gas pressure can be calculated using Equation 1:

$$P_{gas} = P_{atm} + \rho_{air}.\ g.h \quad (1)$$

Where:
P_{gas} = gas pressure (Pa)
P_{atm} = atmospheric pressure (Pa)
ρ_{air} = water density (kg/m^3)
g = gravitational force (m/s^2)
h = height of the water in the manometer (m)

Gas volume measurement

This observation is made after three days of fermentation with a measurement interval of 3 days. The measurement is made by inserting the gas from the container into a measuring device, as seen in the reference [12]. This method is known as the water displacement method.

The principle of the biogas volume measurement device is as follows: First, water is added to pipes 2 and 1, and then the gas holder is connected to pipe 1. After that, pipe one is pulled up, and the gas in the gas holder automatically enters pipe 1. The measurement of the height changes in pipe one is then performed to obtain the volume of biogas using equation 2:

$$V = 1/4 \times \pi \times D \times h \quad (2)$$

Where:
V = the volume of biogas formed
π = 3.14
D = the diameter of pipe 1
h = the height change that occurs in pipe 1

The biogas production rate is measured to determine the volume of biogas formed each day, which serves as a benchmark for calculating the biogas production rate in each digester tube. The biogas production rate can be calculated using Equation 3:

$$\bar{V} = V/day \quad (3)$$

Where:
$\bar{V}$ = biogas production rate
V = the volume of biogas formed in 3 days.

Results and Discussion

The effect of mixture variations on the C/N ratio

Results of the C/N ratio measurement of various mixtures of raw materials for biogas production can be seen in Table 1.

Table 1. Substrate C/N ratio

Sample	C	N	C/N
G1	42.1	1.05	40.22
G2	38.33	1.25	30.54
G3	34.48	1.38	25.03
G4	34.32	1.48	23.17
G5	30.32	1.41	21.50

The data in Table 1 shows that the higher the litter content in the substrate, the higher the C/N ratio value will be. Livestock waste generally has a higher nitrogen than carbon content [13]. On the other hand, agricultural waste usually has a higher carbon content than its nitrogen content [14]. This can be utilized to improve the decomposer's or bacteria's performance by mixing high N content of livestock waste to provide an optimal C/N ratio for biogas production. It was explained that substrate with a high C/N ratio, when mixed with substrate with a low C/N ratio, will provide an average input composition ratio according to the optimal biogas production desired [15]. According to previous work, the optimum C/N ratio for anaerobic digesters ranges from 20-30 [16]. A C/N ratio that is too high or too low will result in suboptimal biogas production. The research results show that sample G1 has a C/N ratio outside of the optimal condition mentioned.

Impact on acidity level (pH)

The substrate pH value in anaerobic digesters affects the growth of methanogenic microorganisms and influences several important compounds for the fermentation process, such as ammonia, sulfide, and organic acids [17]. Therefore, the initial and final pH values must be measured to determine whether the pH value suits the anaerobic fermentation process for biogas. Methane formation occurs within a relatively narrow pH range, which is around 5.5 - 8.5, with an optimal range between 7.0 - 8.0, and this process will be inhibited if the pH drops below 6.0 or rises above 8.3. Figure 1 compares the initial and final pH of biogas fermentation.

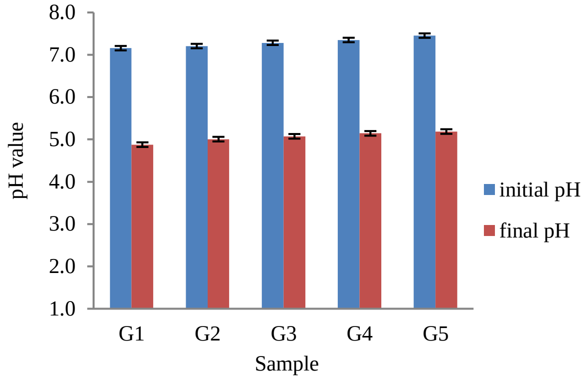

Figure 1. Initial and final pH of substrate

In Figure 1, it can be seen that the final pH value decreases. This indicates that the fermentation process in the digester will change the pH value of the substrate. According to other work, volatile fatty acids are formed in one of the stages of anaerobic organic matter decomposition, namely the stage of acidogenesis and acetogenesis, which will lower the pH of the substrate [8].

Impact on in-digester temperature

The condition of the digester is one of the important things in the fermentation process. It was stated that a good reactor should be able to provide stable operational conditions and not be affected by its environment [18]. Insulation made of soil wrapped with 50 kg sacks is used to maintain the digester temperature stable. Temperature observation data can be seen in Table 2. The table shows that the temperature inside the digester is in the range of 24-30°C. This temperature range is the best condition for microorganisms to grow and develop. Also, it indicates that organic matter degradation has occurred, producing methane gas, CO_2, and heat. Temperature is an important factor for microorganism activity in anaerobic biological processes. Based on previous work, the best temperature range for liquid waste is between 20-45°C and the liquid waste is digested for 18-28 days.

Table 2. In-digester temperature

Day	In-digester temperature (°C)					
	G1	G2	G3	G4	G5	Ambient temperature
3	28.2	28	28.2	27.6	27.2	31
6	28.7	28.4	30	28.5	27.7	31.5
9	28	28	30	29.5	30	30
12	29.5	29.3	30.4	29.6	30	31.7
15	29.2	29.5	31	29	30	32
18	28.8	27	29.3	28.2	29	30
21	26.8	27	29	28	29	29
24	25	26	29	28	28	29.3
27	25.5	25.7	28	27	27.2	30
30	25.5	25.3	28.8	27	27.7	31

Meanwhile, it was stated that methanogenic bacteria are not active at very high or too low temperatures [19]. Satisfactory gas production occurs in the mesophilic range, between 25-30°C. Biogas produced at temperatures outside of this range have a higher carbon dioxide content. Based on the previous research results, the current research results show similarities and indicate that the temperature in this study is optimal.

Impact on in-digester pressure

The gas pressure generated can be determined by observing the changes in the height of the gas pressure measuring instrument. This U-tube manometer is carried out once every three days. Furthermore, the gas pressure in the digester during fermentation can be calculated using Equation 1. The gas pressures generated in each digester are shown in Figure 2. Figure 2 shows that the pressures generated for each sample variation are different. In samples G1 and G2, the pressure generated peaked on days 10 to 12, 102422.6 Pa for G1 and 102540.2 Pa for G2.

Meanwhile, for samples G3, G4, and G5, the pressure generated peaked on days 13 to 15, which was 103206.6 Pa for G3, 102677.4 Pa for G4, and 103138 for G5. The temperature inside the digester influences the difference in pressure from each sample. The higher the temperature, the higher the pressure because high temperatures will cause gas to expand. In addition to temperature, the volume of gas produced may also affect the pressure inside the digester.

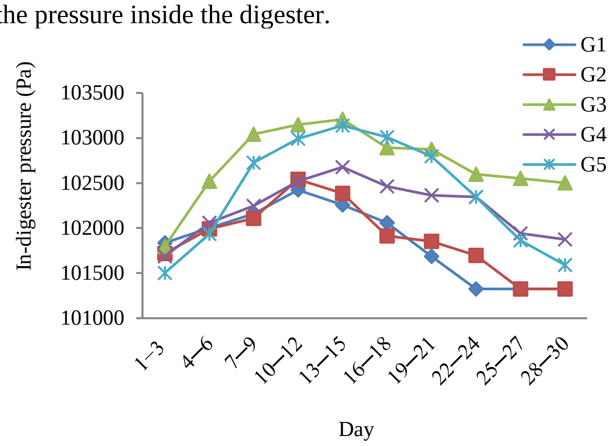

Figure 2. In-digester pressure

Impact on biogas volume-produced

The volume of biogas obtained from measurements is shown in Figure 3. The study results show that the volume of biogas produced continues to increase until day 15. This is because during the hydrolysis, acidification, and methane gas formation stage, the decomposer bacteria continue to grow and be active every day [20]. The biogas produced in each sample has a different volume. The longest biogas production duration was found in samples G3, G4, and G5.

Meanwhile, the lowest biogas production occurred in sample G1, which stopped producing biogas on days 22-24, and G2, which stopped on days 25-27. In samples G1 and G2, the volume peaked on days 10-12, while for G3, G4, and G5, the volume peaked on days 13-15. After reaching peak production, the gas produced the next day will start to decrease. In this study, the decrease in gas production in G5 was much larger compared to G3 and G4.

From the figure, it can also be seen that the ideal mixture of cow manure and litter to produce biogas is shown by sample G3. Bacteria involved in the anaerobic process require several elements according to the needs of living organisms, such as food sources and optimum environmental conditions [21]. Anaerobic bacteria consume carbon about 30 times faster than nitrogen. Balanced composition in the raw material used positively impacts biogas production.

Observing the C/N ratio, it can be seen that sample G3 has the best ratio. This is because a high C/N ratio will cause nitrogen to be quickly consumed by methanogen bacteria to meet its growth needs, and only a little will react with carbon, resulting in low biogas production. On the other hand, if the C/N ratio is low, nitrogen will be released and accumulate in the form of ammonia (NH_4), which can increase pH [22].

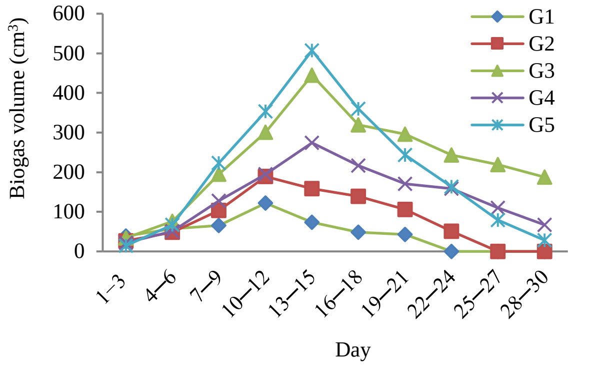

Figure 3. Biogas volume-produced

Biogas production rate

The calculation of the biogas formation rate aims to determine the volume of biogas formed each day in each digester tube. The biogas formation rate is presented in Figure 4. Based on the figure, the best sample was obtained in G3 with an average daily biogas formation rate of 77.22 cm^3. This is because biogas production in sample G3 still occurs significantly after reaching its peak production on days 13-15. This differs from sample G5, where biogas production drastically decreased after reaching its peak on the same day. This may be due to a well-balanced mixture of cattle manure and litter, producing good production.

Meanwhile, the lowest biogas formation rate was obtained from the G1 variation, with an average daily biogas formation rate of 14.95 cm^3. This may be due to a very high C/N ratio in G1, which is 40.22, exceeding the optimum C/N ratio. As a result of the high C/N ratio, nitrogen is consumed very quickly by methanogenic bacteria, resulting in low methane production. Similarly, differences in biogas production between samples are due to differences in the availability of nutrients or energy sources for anaerobic bacteria in each composition, which affects the fermentation rate.

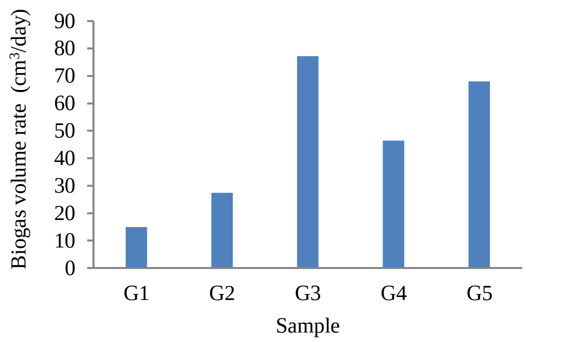

Figure 4. Produced biogas volume rate

Conclusion

The study concludes that the concentration of chicken litter in the substrate significantly influences the C/N ratio and pH value. Increasing chicken litter concentration raises the C/N ratio while lowering pH, emphasizing the need for precise substrate balance in optimizing biogas production. Fermentation consistently reduces pH across all samples, indicating a characteristic outcome. The optimal C/N ratio for biogas production is 25.03, achievable with balanced cow dung and chicken litter composition. This ratio enhances microbial activity, increasing biogas yield. Sample G3, with a 50% cow dung and 50% chicken litter combination, exhibits the highest biogas volume among variations, highlighting substrate composition's crucial role. These findings stress the importance of careful substrate management for efficient biogas production.

References

[1] Martins, F., Felgueiras, C., Smitkova, M., & Caetano, N. (2019). Analysis of fossil fuel energy consumption and environmental impacts in European countries. *Energies*, *12*, 1–11.

[2] Tabatabaei, M., Aghbashlo, M., Valijanian, E., Kazemi, S. P. H., Nizami, A. S., Ghanavati, H., Sulaiman, A., Mirmohamadsadeghi, S., & Karimi, K. (2020). *A comprehensive review on recent biological innovations to improve biogas production, Part 1: Upstream strategies* vol 146. Elsevier Ltd.

[3] Xu, Z. X., Song, H., Zhang, S., Tong, S. Q., He, Z. X., Wang, Q., Li, B., & Hu, X. (2019). Co-hydrothermal carbonization of digested sewage sludge and cow dung biogas residue: Investigation of the reaction characteristics. *Energy, 187*, 115972.

[4] Wang, Z., Ali, S., Akbar, A., & Rasool, F. (2020). Determining the influencing factors of biogas technology adoption intention in Pakistan: The moderating role of social media. *International Journal of Environmental Research and Public Health, 17*(7), 2311**.**

[5] Kapoor, R., Ghosh, P., Kumar, M., Sengupta, S., Gupta, A., Kumar, S. S., Vijay, V., Kumar, V., Kumar, V. V., & Pant, D. (2020). Valorization of agricultural waste for biogas based circular economy in India: A research outlook. *Bioresource Technology, 304*. 123036.

[6] Rattanaphan, S., Rungrotmongkol, T., & Kongsune, P. (2020). Biogas improving by adsorption of CO_2 on modified waste tea activated carbon. *Renewable Energy, 145*, 622–631.

[7] Barber, W. P. F. (2016). Thermal hydrolysis for sewage treatment: A critical review. *Water Research, 104*. 53–71.

[8] Vijin, P. A., Sivaram, A. R., Prabhu, N., & Sundaramahalingam, A. (2021). A study of enhancing the biogas production in anaerobic digestion. *Materials Today Proceedings*, *45*(9). 7994–7999.

[9] Herrero, G. N., Benedetti, M., & Bolzonella, D. (2019). Effects of Enzymes Addition on Biogas Production From Anaerobic Digestion of Agricultural Biomasses. *Waste and Biomass Valorization*, 10, 3711–3722.

[10] Bhatnagar, N., Ryan, D., Murphy, R., & Enright, A. M. (2020). Trace element supplementation and enzyme addition to enhance biogas production by anaerobic digestion of chicken litter. *Energies, 13*(13), 3477.

[11] Tira, H. S., Padang, Y. A., & Sukrenewita, I. K. (2021). Analysis of cross-sectional area of digester on biogas production rate. *Dinamika. Teknik Mesin, 11*(1)**,** 68-73.

[12] Tira, H. S., & Umbara, E. G. (2018). Evaluasi efektifitas effective microorganism-4 (EM-4) dalam menaikkan volume produksi biogas. *Dinamika Teknik Mesin, 8*(1), 40–44.

[13] Zeng, W., Wang, D., Wu, Z., He, L., Luo, Z., & Yang, J. (2021). Recovery of nitrogen and phosphorus fertilizer from pig farm biogas slurry and incinerated chicken manure fly ash *Science of the Total Environment. 782*, 146856.

[14] Parsaee, M., Kiani, D., & Karimi, K. (2019). A review of biogas production from sugarcane vinasse. *Biomass and Bioenergy, 122*, 117–125.

[15] Xue, S., Wang, Y., Lyu, X., Zhao, N., Song, J., Wang, X., & Yang, G. (2020). Interactive effects of carbohydrate, lipid, protein composition and carbon/nitrogen ratio on biogas production of different food wastes. *Bioresource Technology, 312,* 123566.

[16] Yan, L., Liu, C., Zhang, Y., Liu, S., & Zhang, Y. (2021). Effects of C/N ratio variation in swine biogas slurry on soil dissolved organic matter: Content and fluorescence characteristics. *Ecotoxicology and Environmental Safety, 209,* 111804.

[17] Purba, R. A. P., Yuangklang, C., & Paengkoum, P. (2020). Enhanced conjugated linoleic acid and biogas production after ruminal fermentation with piper betle l. Supplementation *Ciencia Rural, 50*(7), 1–10.

[18] Kamyab, B., & Zilouei, H. (2021). Investigating the efficiency of biogas production using modelling anaerobic digestion of baker's yeast wastewater on two-stage mixed-UASB reactor. *Fuel, 285*, 119198.

[19] Du, J., Qian, Y., Xi, Y., & Lü, X. (2019). Hydrothermal and alkaline thermal pretreatment at mild temperature in solid state for physicochemical properties and biogas production from anaerobic digestion of rice straw. *Renewable Energy, 139,* 261–267

[20] Li, K., Wang, K., Wang, J., Yuan, Q., Shi, C., Wu, J., & Zuo, J. (2020). Performance assessment and metagenomic analysis of full-scale innovative two-stage anaerobic digestion biogas plant for food wastes treatment. *Journal of Cleaner Production. 264*, 121646.

[21] Carrillo-Reyes, J., Buitrón, G., Arcila, J. S., & López-Gómez, M. O. (2021). Thermophilic biogas production from microalgae-bacteria aggregates: biogas yield, community variation and energy balance. *Chemosphere, 275*, 129898.

[22] Miah, M. R., Rahman, A. K. M. L., Akanda, M. R.,

Pulak, A. & Rouf, M. A. (2016). Production of biogas from poultry litter mixed with the co-substrate cow dung *Journal of Taibah University for Science, 10*(4), 497–504.