ISSN:2716-9227 Algerian Journal of Engineering and Technology 06 (2022) 079–084 e-ISSN: 2716-9278

Algerian Journal of Engineering and Technology

Journal homepage: https://jetjournal.org/index.php/ajet

Original Article

Improving biogas production from animal manure by batch anaerobic digestion

Muetaz Mohammed*, Ahmad Belkair, Tarek Hamad, Abraheem Jirhiman, Razena Hassan, Ali Ahmeedah

Department of Sustainable and Renewable Energy Engineering, Omar Al-Mukhtar University, El-Beida, Libya

ARTICLE INFO

Article history:
Received 29 April 2022
Revised 21 May 2022
Accepted 26 May 2022

Keywords:
Biogas;
Effect pH;
Photoreactor;
Animal Manure;
Batch Digestion.

ABSTRACT

In Libya, even if the production of biogas started in the last years, still there is too much need to optimize the biogas resources. This paper examined improving cow, sheep, and poultry manure in two phases. The experiment was carried out in a 2000 mL digester put in bath water at 37 °C. The mixing ratio of animal manure and water used was 1:1 in 12 days of Hydraulic Retention Time (HRT). The produced gas was measured by the volumetric water replacement method. In the first phase, the best pH was chosen in the experimental test with different pH ranges. Three set-ups were prepared with different pHs (6.5, 7, 7.5). The results showed that the pH had significant effects on biogas yield, where pH 7 had the highest biogas production and pH 6.5 had the lowest. In the second phase, the effect of insulation of digester on the biogas yield of cow, sheep, and poultry manure was investigated. The experiments showed that the biogas produced from an insulated digester was higher than the transparent digester. Therefore, it is assumed that the study, which gives a maximum yield of biogas production from the batch digestion process, might meet future energy demand.

1. Introduction

Fossil fuel is currently the world's main source of energy and is prevalent in forms such as crude oil, hard coal, and natural gas. Such fuels are not renewable energy sources as they were formed over hundreds of millions of years but are consumed at a much faster rate than the rate at which new fossil fuels are being formed. One of the largest disadvantages associated with the use of fossil fuels is that harmful greenhouse gasses such as carbon dioxide are released when it is burnt during energy production processes. This is especially true during the production of electricity via coal-fired power plants [1].

In recent years, the energy sector has received increased attention due to the concern of an oil shortage. Additionally, concerns such as the greenhouse effect and the general depletion of energy reserves have played a significant role in the debate. This has caused the development of a range of new energy technologies such as wind energy, solar energy, and biomass energy [2,3].

The anaerobic digestion of biomass to produce biogas is considered to be a model for choosing the best alternative sources of energy for rural areas using the reasoning that it is cheap and can be locally produced and used. Also, the biogas produced can be used for a number of purposes such as heating, lighting, fuel for cooking, and local or on-the-grid electric power generation [4].

Animal manures can be used as sources of biomass-based conversion processes, especially in bio-energy and bio-fertilizer production. Nowaday, developed countries tend to decrease the number of farmers but increase the number of animals. This trend is also transforming livestock production in developing countries [5]. Livestock contributes to nearly 40% of the total agricultural

* *Corresponding author*.Tel.: +218918552189
E-mail address: Moutaz.benali@omu.edu.ly
Peer review under responsibility of University of El Oued.
 DOI: https://doi.org/10.57056/ajet.v6i1.74

production in developed countries and 20% in developing countries, supporting the livelihoods of at least 1.3 billion people worldwide, since 34% of the dietary protein supply comes from livestock [6].

The specific amount of cattle manure per animal relies on many aspects such as feeding regime, stage of the process, type of production system, etc., and the method of housing used [7]. Livestock activities have an environmental impact when manure is not effectively managed [8,9]. On the other hand, animal manure is considered an attractive natural resource for renewable energy production, and can also replace industrial fertilizers and improve soil fertility [10,11].

Anaerobic digestion can take place at psychrophilic temperatures below 20 C but most reactors operate at either mesophilic temperatures or thermophilic temperatures, with optima at 35 C and 55 C, respectively. The methane yields that are obtained at a temperature of 20°C is about 42% of the yields achieved at 35°C [12]. The percentage of methane in biogas produced under thermophilic conditions (55°C) is on average 2% higher when compared with biogas produced under mesophilic conditions(35°C). It has been shown that temperature has almost no effect on the ultimate methane yield of beef cattle manure for temperatures between 30 and 60°C [13].

In a study evaluating the influence of diet and of the period on the anaerobic digestion of cows, Orrico et al [14] observed that only the diet had an effect under the digestion process. The authors observed that the proportion with the highest amount of concentrate (40% roughage and 60% concentrated) led to greater efficiency in the gas production compared to the 60% roughage and 40% concentrated diet with a biogas production potential of 420 mL/g.

Barros et al. [15] evaluated the biogas production in an Indian digester with a capacity of 7 m^3, using cow manure as substrate. In the two-month period, the researchers observed a cumulative production of 5.025 L. In addition, Weber [16] while studying the biogas production from cow manure by using a vertical continuous digester, with a capacity of 20 m^3, observed production of 396.850 L of biogas in four months.

several studies have shown that co-digestion of organic wastes, such as animal manure combined with industrial, agricultural, and municipal wastes, is a viable option [17]. However, the low rate of biodegradation of fibrous wastes, such as manure, proves that an anaerobic digestion process for biogas production based solely on these substrates may be difficult, whereas the addition of substrates with lower fiber contents facilitates a more rapid initiation and increase in the biogas yield.

Previous studies have investigated the use of cow manure that was co-digested with different wastes to increase biogas production and methane yields. Cunsheng et al.[18] reported that co-digestion of cattle manure with food waste in batch mode at an optimal ratio of 2:1 (manure : food waste) increased methane production by 41%, from 2624 ml to 3725 ml, compared to mono-digestion.

Benali et al.[19] studied the effect of solid concentrations on anaerobic digestion of cow manure. This study aimed to determine the optimum water dilution which will produce the high biogas yield. Three batch set-ups; CM1, CM2, and CM3 of uniform amounts of cow manure were prepared with different water dilution conditions. The results of accumulated biogas yield at the end of an experiment were 5.38L, 3.96L, and 3.4L for CM2, CM1, and CM3.

In another study, Benali et al. [20] comparedthe biogas production from cow, chicken, and sheep manure to determine the best sample from animal waste for the biogas production. This study showed that the maximum value of biogas was produced by chicken manure, followed by sheep and cow respectively.

In Libya, even if the production of biogas started in the last years, still there is too much need to optimize the biogas resources. This study provides strong evidence that the concept of improving biogas yield through the paint the reactor black color and determining the optimum pH of cow, sheep, and poultry livestock manure.

2. Materials and Methods

The experimental set-up was made to study the effect of pH and the insulation of the reactor on the biogas production of cow, sheep, and poultry manure. A reactor made of a plastic bottle of 2 liters capacity was used for set-up. A schematic of the biogas production unit is shown in Figure 1. The reactor was linked with a displacement bottle and water collector. Rubber tubes were used to link the reactors and the displacement bottles. The digestion process was done in the water bath at 37°C as shown in Figure 2. The three reactors were operated in batch type and fed manually and the rate and the pattern of gas produced were closely monitored over a period of 12 days to ascertain the highest yield of the gas.

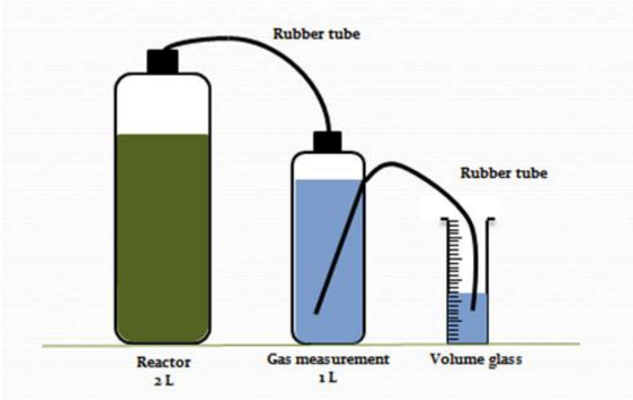


Fig 1. Biogas production unit.

Fig 2. The water bath laboratory.

In this research work, Phase I and phase II of the experiment were carried out using fresh manure of poultry (PM), cow (CM), and sheep(SM). Phase I was conducted to verify the effect of pH on biogas production, while phase II Investigated the effect of insulation of digester on biogas production. The characteristics of the experiments are shown in Table 1.

Table 1. The details of the experiment.

Mass of manure	560 g
Volume of water	560 ml
Temperature	37 0c
Hydraulic retention time	12 days
Measurement of biogas production	Daily (24hr)

3. Results and Discussion

3.1. Effect of the pH and the type of Manure on biogas production

Figure 3 shows the daily biogas yield over 12 days retention period from PM, CM, and SM at various pH conditions. Gas production was increasing on the first days and then declined with the passage of days. On the first day, PM produced 741 ml, 722 ml, and 641 ml at pH 6.5, 7, and 7.5 respectively, while the CM produced, on the first day, 653ml,610ml and 515 ml at pH 6.5, 7, and 7.5 respectively, Finally, the SM produced 386ml,387ml, and 363ml at pH 6.5, 7 and 7.5 respectively. The result showed that PM produced the highest biogas production at each pH level, followed by CM, and the lowest by SM.

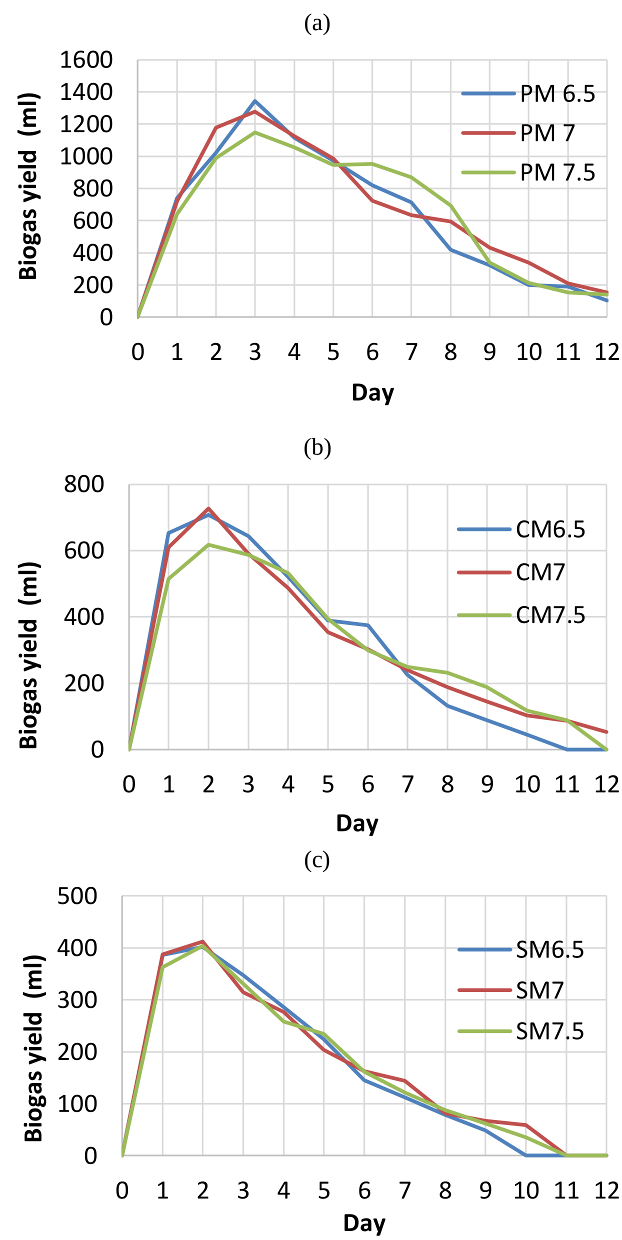


Fig 3. Daily biogas yield from (a) PM; (b) CM; (c) SM.

Figure 4 shows the total biogas yield from PM, CM, and SM at various pH conditions. It is observed that the highest amount of gas production was at pH 7, then pH 7.5, and finally pH 6.5 in all substrates. In the case of PM, the biogas produced from pH 7 was higher than the gas produced from pH 7.5 by 2.9% and the gas produced from pH 7.5 was higher than the gas produced from pH 6.5 by 2.3%. For CM, the gas produced from pH 7 was higher than the gas produced from pH 7.5 by 1.78 % and the gas produced from pH 7.5 was higher than the gas produced from pH 6.5by 1%.Finally, in the case of SM, the total biogas produced from pH 7 was higher than the gas produced from pH 7.5 by 1.1 % and the gas produced from pH 7.5 was higher than the gas produced from pH 6.5 by 1.4 %. this is results correspond with the study by Jayaraj, et al.(2014). The reason the pH of the substrate has a significant effect on biogas production is because it affects the activity of bacteria that destroy organic matter in biogas. A low pH in the digester inhibits the activity of microorganisms involved in the digestion process, particularly methanogenic bacteria.

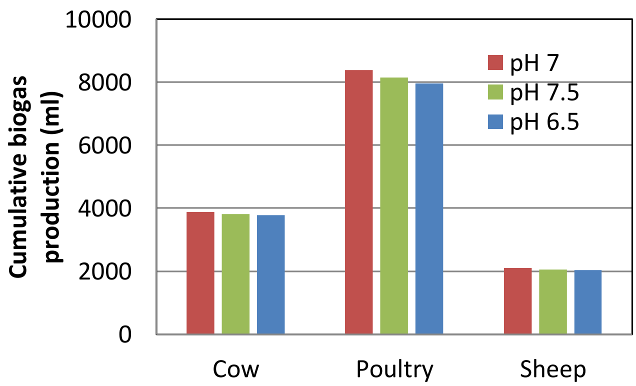


Fig 4. Cumulative biogas yield from PM, CM ,and SM.

3.2. *Effect of insulating the reactor on biogas production*

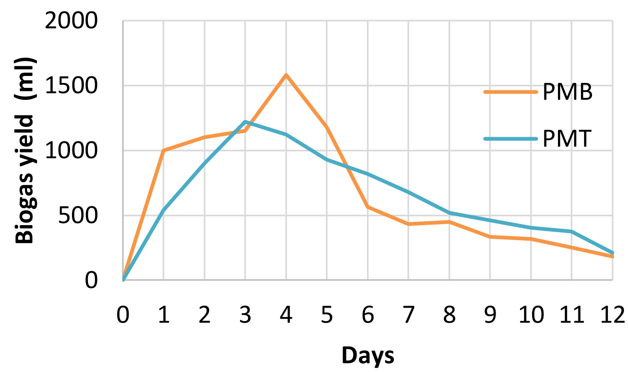
The results showed that coated reactor with black color and type of manure had a significant effect on biogas yield as shown in Figure 5. PM produced the highest average yield while SM produced the least (Table 2).

Table 2. The effects of insulation of reactor and type of manure on biogas production.

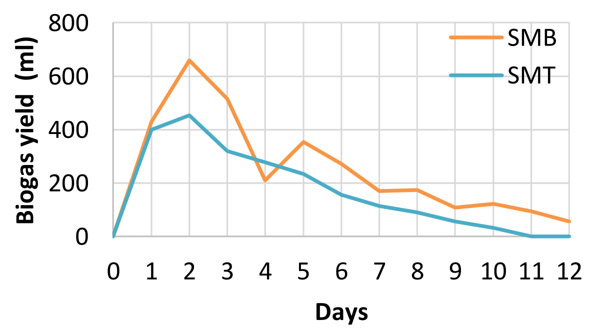
Parameter	Transparent			Black		
Manure type	CM	PM	SM	CM	PM	SM
Temperature (^{0}c)	37	37	37	37	37	37
PH	6.1	5.74	6.54	7.03	5.99	6.67
Avg. daily biogas production (ml)	318	682	177.5	325	711.5	263.33
Standard Deviation	117.6	201.8	96.7	149.9	283.1	106.9

Figure 6. Shows the average daily biogas production of the black and photoreactor from the PM, CM, and SM. The result shows that the black reactor produced higher biogas than the photoreactor. This is attributed to the fungi that produce oxygen grow inside the transparent anaerobic digester. They affect the activity of anaerobic bacteria that are responsible for the production of biogas inside the reactor.

(a)



(b)



(c)

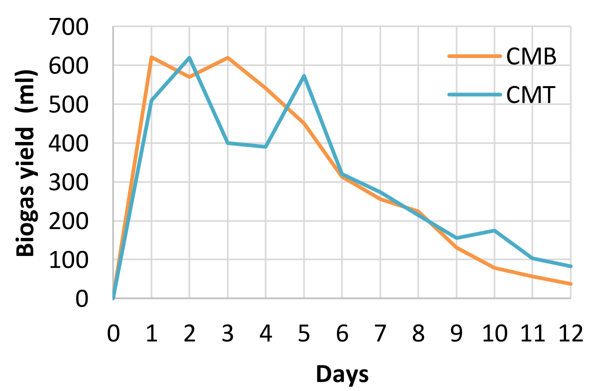


Fig 5. Biogas yield during digestion in (a) PM; (b) SM; (c) CM.

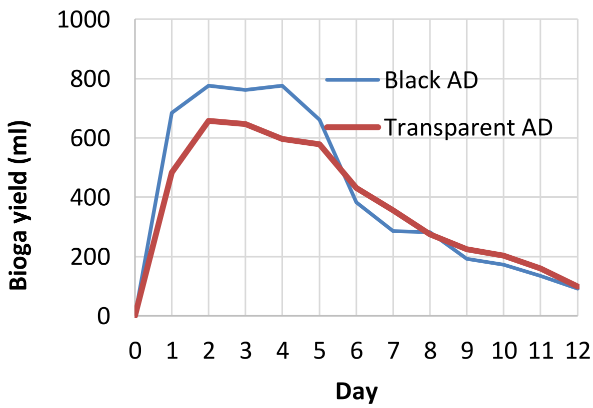


Fig 6. Average biogas yield in Black reactor and Transparent reactor of three different types of animal manure (PM, CM, and SM).

4. Conclusion

This study investigated the effect of pH (6.5, 7, 7.5) and the insulation of digester on biogas production from poultry, cow, and sheep manure (which are the most available in our location) in an anaerobic batch reactor with a retention time of 12 days. The results showed that the pH had significant effects on biogas yield, where pH 7 had the highest biogas production and pH 6.5 is the lowest. Insulation of anaerobic digester had significant effects on biogas yield, where the black anaerobic digestion produced biogas higher than the transparent anaerobic digestion. The animal manure species affected the biogas production as well, where the highest biogas production was obtained for PM, and then CM and SM respectively.

5. Recommendations

The researchers suggest expanding the experiment to include all types of animal manure. In addition, it is suggested to study the effect of farms and barns feeding on biogas production.

Acknowledgements

The authors acknowledge the kind support of the Department of Sustainable and Renewable Energy Engineering, Omar Al-Mukhtar University.

Conflict of Interest

The authors declare that they have no conflict of interest

References

1. International Energy Agency, Energy and Climate Change. World Energy Outlook Special Report, OECD/IEA, Paris, 2015.
2. United Nations Environment Programme, The Emissions Gap Report. A UNEP Synthesis Report, UNEP, Nairobi, 2014.
3. Charles W, Barbara G. Biotechnology for production of fuels, chemicals and materials from biomass, *Applied Biochemistry and Biotechnology*. 1993; 39: 41–59.
4. Mata-alvarez J, Mace S, Llabres P. Anaerobic digestion of organic solid wastes – an overview of research achievements and perspectives, *Bioresource Technology*. 2000; 74: 3–16.
5. FAO. World Livestock: Transforming the Livestock Sector through the Sustainable Development Goals; Food and Agriculture Organization of the United Nations: Rome, Italy, 2018.
6. Meat Atlas Facts and Facts and figures about the animals we Eat. Berlin, Germany; Heinrich Böll Foundation and Friends of the Earth Europe: Brussels, Belgium, 2014.
7. Ogbuewu P, Odoemenam U, Obikaonu O, Opara N, Emenalom O, Uchegbu C, Okoli C, Esonu O, Iloeje U. The growing importance of neem (Azadirachta indica A. Juss) in agriculture, industry, medicine and environment: A review. *Research Journal of Medicinal Plant*. 2011; 5(3): 230–245.
8. Chadwick D, Sommer S, Thorman R, Fangueiro D, Cardenas L, Amon B, Misselbrook T. Manure management: Implications for greenhouse gas emissions. *Animal Feed Science Technology*. 2011; 166–167: 514–531.
9. Webb J, Sommer G, Kupper T, Groenestein K, Hutchings J, Eurich-Menden B, Rodhe L, Misselbrook H, Amon B. Emissions of ammonia, nitrous oxide and methane during the management of solid manures. *Agroecology and Strategies for Climate Change*. 2012; 8: 67–107.
10. Nielsen B, Mladenovska Z, Westermann P, Ahring K. Comparison of two-stage thermophilic (68 °C/55 °C) anaerobic digestion with one-stage thermophilic (55 °C) digestion of cattle manure. *Biotechnology Bioengineering*. 2004; 86(3):291–300.
11. Tallou A, Haouas A, Jamali Y, Atif K, Amir S, Aziz F. Review on cow manure as renewable energy. In Smart Village Technology: Concepts and Developments; Patnaik S, Sen S, Mahmoud M.S, Eds.; Springer International Publishing: Cham, Switzerland. 2020; 17: 341–352.
12. Kaparaju P, Rintala J. Effects of temperature on post-methanation of digested dairy cow manure in a farm-scale biogas production system. *Environmental Technology*. 2003; 24: 1315- 1321.
13. Vindis P, Mursec B, Janzekovic M, Cus F. The impact of mesophilic and thermophilic anaerobic digestion on biogas

production. Journal *of Achievements in Materials and Manufacturing Engineering*. 2009; 36 (2): 192-198

14. Orrico J, Orrico A, Lucas J, Sampaio A, Fernandes A, Oliveira E. Biodigestão anaeróbia dos dejetos da bovinocultuta de corte: influência do período, do genótipo e da dieta. *Revista Brasileira de Zootecnia*. 2012; 41 (6): 1533-1538.
15. Barros R, Tiago F, Nascimento Y, Gushiken E, Calheiros H, Silva F, Stano J.Estudo da produção de biogás da digestão anaeróbia de esterco bovino em um biodigestor. *Revista Brasileira de Energia*. 2009; 15: 34-38.
16. Weber R. Produção de biogás com relação ao teor de sólidos voláteis dos dejetos de bovinocultura de leite. *Revista Brasileira de Energias Renováveis*. 2014; 3 (1):43-55.
17. Fatma A, Yuzaburo N, Maria K, Naomichi N, Yutaka N. Enhancement of methane production from co-digestion of chicken manure with agricultural wastes. *Bioresource Technology*. 2014; 159: 80-87.
18. Cunsheng Z, Gang X, Liyu P, Haijia S, Tianwei T. The anaerobic co-digestion of food waste and cattle manure. *Bioresource Technology*. 2013; 129: 170–176.
19. Benali M. Utilization of Cow, Poultry and Sheep Manure for biogas Production: A Comparative Analysis, *Master's thesis, Faculty of Engineering*, Omar Al-Mukhtar University, Libya, 2o2o.
20. Benali M. Experimental Investigation of Biogas Production from Cow Dung in an Anaerobic Batch Digester at Mesophilic Conditions. *Iranian (Iranica) Journal of Energy & Environment*. 2019;10 (2):121-125.
21. Jayaraj S, Deepanraj B, Sivasubramanian V. Study on the effect of ph on biogas production from food waste by anaerobic digestion. *The 9th international green energy conference*. 2014; 799-805.

Recommended Citation

Mohammed M, Belkair A, Hamad T, Jirhiman I, Hassan R, Ahmeedah A. Improving biogas production from animal manure by batch anaerobic digestion. *Alger. J. Eng. Technol. 2022*, 6:79-84. DOI: https://doi.org/10.57056/ajet.v6i1.74