Communication in Physical Sciences 2020, 5(4): 619-626

Production and Purification of Biogas Generated by Co-digestion of Cow Dung and Kitchen Waste

M. Runde*, M. H. Shagal and Y. Abba
Received 29 July 2020/Accepted 26August 2020/Published online: 31 August 2020

Abstract *This study was designed to produce biogas from co-digestion of cow dung and kitchen waste. 20 litres digester and gas collection systems were prepared from locally available materials. The feed materials were collected locally, pre-fermented, digested and analysed. Purification of the produced biogas was carried out by passing the gas through three chambers containing 40% KOH, CaO. activated charcoal and silica gel/activated charcoal respectively. The flame of the combusting purified biogas was observed to be more intense than that of the freshly produced impure biogas both in colour and height. The study confirmed that biogas can easily be generated and purified using locally and cheaply available raw materials.*
Key Words: *Biogas, cow dung, co-digestion, fuel, renewable.*

Musa Runde
Department of Pure and Applied Science,
Faculty of Science, National Open University of Nigeria, 91 Cadastral Zone, Nnamdi Azikiwe Expressway, Jabi-Abuja, Nigeria
Email: rmusa@noun.edu.ng
Orcid id: 0000-0001-9312-0455

M. H. Shagal
Department of Chemistry,
Faculty of Science, Modibbo Adama University of Technology,
P.M.B 2075 Yola Adamawa State
Email: shagal5787@yahoo.com
Orcid id: 0000-0003-0550-2360

Y. Abba
Department of Science Laboratory Technology,
Faculty of Science, Modibbo Adama University of Technology, P.M.B 2075 Yola Adamawa State
Email: yunusaabba2018@gmail.com
Orcid id: 0000-0001-8479-9427

1.0 Introduction

In the last decade, there has been an increasing focus on waste management. Growing population and economic development have led to a continuous increase in waste generation, which has resulted in development of new technologies for waste management (Letcher and Vallero, 2011). In order to minimize the environmental impact from waste, the Waste Framework Directive (2008/98/EC) has established a waste management hierarchy. This hierarchy defines the priority order for waste management, and ensures a continuous effort to carry out waste management with best practice. New laws are frequently being established in order to improve the framework (Brendeløkken, 2016). According to Bhuiyan (2010), resource recovery and recycling is among the best approaches to waste management. Resource recovery is an approach aim at recovering useful product from waste, i.e waste to wealth process (Sridhar and Hammed, 2014).

Biogas is a fuel gas consisting of a mixture of methane (CH_4), carbon dioxide (CO_2) and traces of other gases, produced through microbial processes under anaerobic conditions from bio-degradable materials. It is a renewable high-quality fuel that burns without leaving soot's or particulate matter (Ossai, 2012). In fact, the contribution of a methane molecule (CH_4) to the greenhouse effect is 21 times greater than that of a carbon dioxide molecule. Therefore, burning methane, even though producing CO_2, reduces its impact on the environment (Lebunu *et al*, 2019). Bioreactors can be used to treat municipal waste and generate electricity (Brendeløkken, 2016). Commercial biogas production has increased for at least two reasons. Firstly, biogas can be used as fuel or energy production. Secondly, it contributes to a lower greenhouse gas (GHG) concentration when it is collected in a closed process (Santos, *et al.,* 2013). Methane is considered a strong greenhouse gas, and by capturing it in a biogas production plant it is not emitted to the atmosphere (Butz, 2014).

Biogas production is a treatment technology that generates renewable energy, and recycles organic waste into a digested biomass, which can be used as

fertilizer and soil amendment (Kumar *et al*, 2015). Carbon footprints from food waste can be reduced by both the recovery of green energy, and the use of biofertilizers instead of chemical fertilizers (Masse, *et al*., 2012). Biogas is a renewable energy source, which is considered carbon-neutral since the organic waste has photosynthesized carbon dioxide (Ossai, 2012). Production of biogas from organic waste has shown to be more environmentally friendly compared to other waste handling options such as landfilling, incineration and composting (Lin, *et al.,* 2012). Biogas production can therefore be considered a favourable treatment for organic waste (Brendeløkken, 2016). It is evident that by anaerobic digestion, biogas can be generated from different materials such as animal dung, sewage, industrial effluents, municipal waste, kitchen waste and any matter that once lived (Eze and Agbo, 2010). Several studies on the production of biogas from waste have been reported. Morales-Polo *et al*. (2019) reported on the great potential of using vegetable and fruit waste for biogas production while Nasir *et al*. (2012) reported on the potential of solid organic waste for biogas production. Similar potential from organic waste for biogas potential was also established by Alelge *et al*. (2018) while Ranade *et al*. (1987) and Zamanzadeh *et al*. (2017) successfully produced biogas from market and food wastes respectively.

Alghoul *et al*. (2019) has also reported the use of food waste for biogas production while Konrad *et al*. (2014) used swine manure supplement with glycerine was for the production of biogas. In most of these studies, plant wastes dominate biogas researches. However, animal wastes have posed more serious management problems than plant waste because of the foul odour that characterised most of them. Therefore, the use of animal waste for biogas production can significantly reduce disposal cost and improve public health. In the need to realise this course, Muthu *et al*. (2017) and Chibueze *et al*. (2017) have independently confirmed that cow dung is a good feedstock for biogas production. Hence the aim of this study is to produce and characterised biogas from cow dung, which is abundant abattoir waste in Nigeria.

2.0 Materials and Methods

2.1 Materials

Fresh cow dung was collected from Campus farm while kitchen waste was collected from household, around the same campus, i.e Modibbo Adama University of Technology.

Reagents used for the study were analar grades and include sodium hydroxide, calcium oxide, activated charcoal, silica gel and distilled water.

Analytical instrument used for the study included Gas Chromatography-Mass Spectrometry (GC-MS), Fourier Transformed Infrared Spectrophotometer, Weighing balance, thermometer (0-100), Volumetric flask, Conical flask, Rubber cork, Rubber hose, Gas delivery tubes, Vehicle tyre tube, Bunsen burner, 20 litre plastic bottle, PVC pipes, PVC gum.

2.2 Methods

2.2.1 Sample collection and preparation

Sample collection and preparation were carried out following the procedure reported by Igboro, (2011). Freshly produced cow dung around Modibbo Adama University of Technology Yola environment, was collected in a clean polyethene bag and transferred to the Chemistry/biochemistry Techniques laboratory for processing. Kitchen waste was obtained from various hostels within the campus.

2.2.2 Preparation of digester

The digester was prepared by using black plastic drum. The choice of the colour of the plastic drum is to facilitate heat energy absorption from the sun while, hoses were provided for gas flow from the digester to the gas storage chamber in this case car tube was used (See Fig. 1).

2.2.3 Gas production, collection and storage

Slurry was prepared by mixing cow dung (3 kg) and food waste with water in a ratio of 3:1. The slurry was fed into the earlier prepared digester. Continuous stirring was done to allow for homogenized mixture and for effective anaerobic digestion to take place. A retention time of 8 days was allowed for generation of biogas. The Biogas was collected from the digester through a 10 mm diameter flexible host connected from the digester to the bottom of the gas collection system and then stored in a car tube as describe by Ikpi *et al*, (2018).

The biogas produce was passed through three different chambers for purification. The first chamber contained 40 % solution of potassium hydroxide, the second, anhydrous calcium oxide and activated charcoal while the third chamber contained silica gel and active charcoal. This method was put in place by utilizing the procedures outlined Divyang and Hemant, (2015). The purified gas was stored in a vehicle tube.

Fig. 1: Biogas production setup

2.2.4 Upgrading of biogas

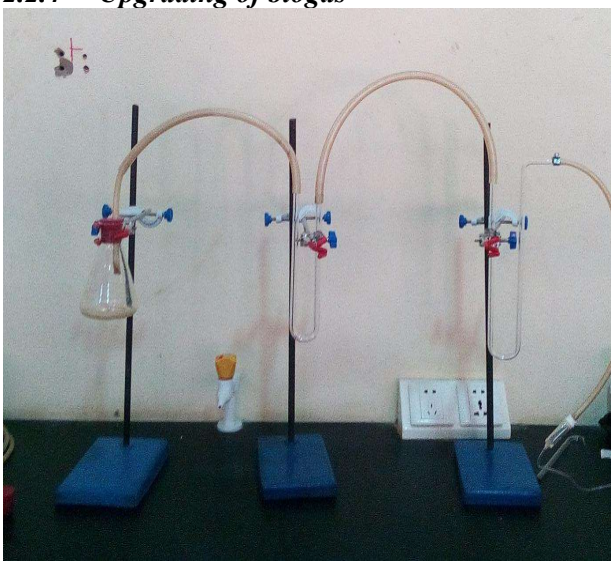

Fig. 2: Biogas purification setup

2.3 Flame analysis

The length of the burning flame for each of the biogases (upgraded and impure) were measured using wooding ruler. The colour of the flame generated through its combustion was also measured.

2.4 GC analysis

The biogas was analysed according to the method described in ASTM D-1945-03. (2010). Gas sampler was used to collect the sample at low pressure. Sample was then prepared using draining water of gas law method. Self-lock tubes and sampling ports was used to prevent any diffusion of the gas sample. The gas sample ~~gas~~ was introduced into the inlet at initial temperature of 36 °C and held for 1 minute and the gradually increased to a maximum oven temperature of 250 °C at a heating rate of 10 °C/minute. Helium was used as mobile phase. The analysis was done using split less mode and inlet temperature of 200 °C. Column used was Agilent J & W DB-35 ms with length of 30 metres, inner diameter of 0.25 and path film thickness of 0.25 μm.

2.4 Infra red spectroscopic analysis

The biogas analysis was conducted using Buck scientific IR spectrometer model 530.The gas was introduced into the tube through it inlet and covered immediately. The sample was analysed by the instrument and the spectrum generated was saved in the system.

3.0 Results and Discussion

Gas production in the digesters started on day 8. Figs. 3 and 4 show the burning flames for the impurified and purified gases respectively.

Fig. 3 Raw biogas flame

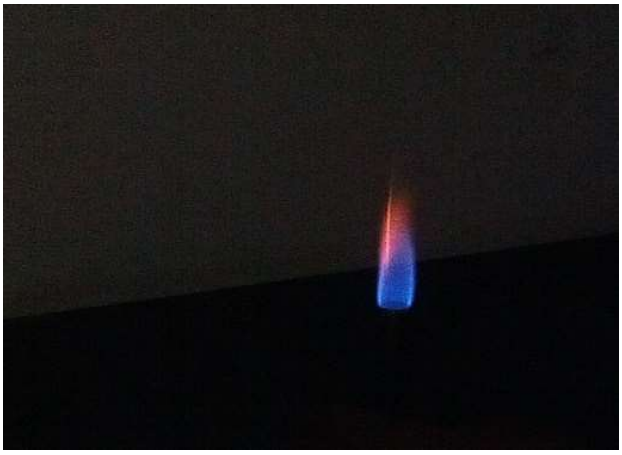

Fig. 4. Purified biogas flame

The measured height of the flame before and after purification of the produced gas are recorded in Table 1

Table 1: Flame height measurement

Gas type	Height of flame (cm)			Mean
Raw gas	17.1	17.6	16.9	17.2
Purified gas	19.8	21.1	21.3	20.7

Low flame height of 17.2 cm (average) was observed when the raw biogas was ignited (Table 1) while high flame height of 20.7 cm (average) was observed after purifying the biogas. Therefore, the purification process might have remove gases (such as carbon (IV) oxide, water vapour, etc) that gave the produced gas a low calorific value (Fandi *et al*., 2016). Increase in CO2 content of a gas will decrease the flame height and also creates larger flame angle. According to Willyanto, (2017), the lesser the amount of N2 in biogas, the greater the laminar burning velocities. Blue and reddish-yellow colour was observed on the flame of the purified biogas while the impure biogas gave blue colour upon combustion. In general, the colour of the flame on the combustion of purified biogas has a blue colour with a reddish yellow mixture while the flame of the impure gas has a blue colour only (Caturwati, *et al*, 2018).

3.2 Infra-Red Spectrometer study

Fig. 5 shows the Fourier Transformed Infrared spectrum of the produced biogas before purification.

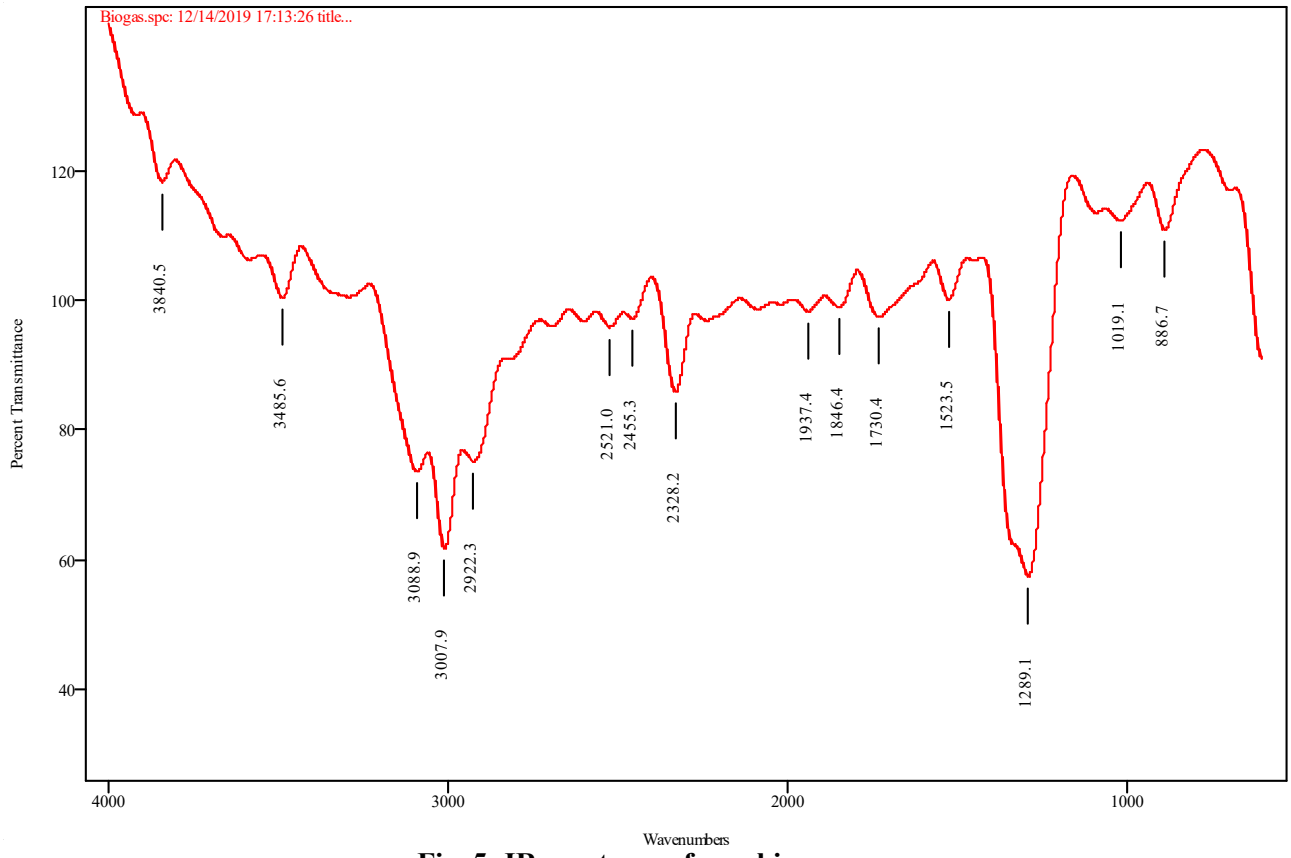

Fig. 5: IR spectrum of raw biogas

Fourier-Transform Infra-Red spectroscopy (FT-IR) have been used to identify functional groups and the bands corresponding to various stretching and bending vibrations in the organic samples (Siwatt, 2004). In this work, IR was used to identify functional groups and bands correlating with the characteristic of gasses present in the biogas produced. The absorption band observed between 3485.6-3840.5 cm-1 indicates the presence of N-H bond of secondary amine. A peak at 2922.3, 3007.9 and 3088.9 cm-1 correspond to C-H bond stretches. The absorptions at 1937.4, 1846.4, and 1730.4 cm-1 correspond to COH (Aldehyde) or C=O (Ketone). A strong sharp peak of 1289.1cm-1 which falls on the Fingerprint region might be C=O stretching bond, according to Wade, (2006).

3.3 GC Analysis Results

Figs. 6 and 7 represent a gas chromatogram (GC) of raw biogas and purified biogas respectively. Generally, GC serve as qualitative techniques for identifying components of gasses or liquids that can easily be volatilised without decomposing. In Fig. 6 above, peaks were observed at the retention time of 3.887, 5.846, 6.034, 6.606, 7.321, and 22.362 minutes. Peaks were characterised as not sharp and numerous at some retention time. This could be attributed to the presence of impurities in the biogas.

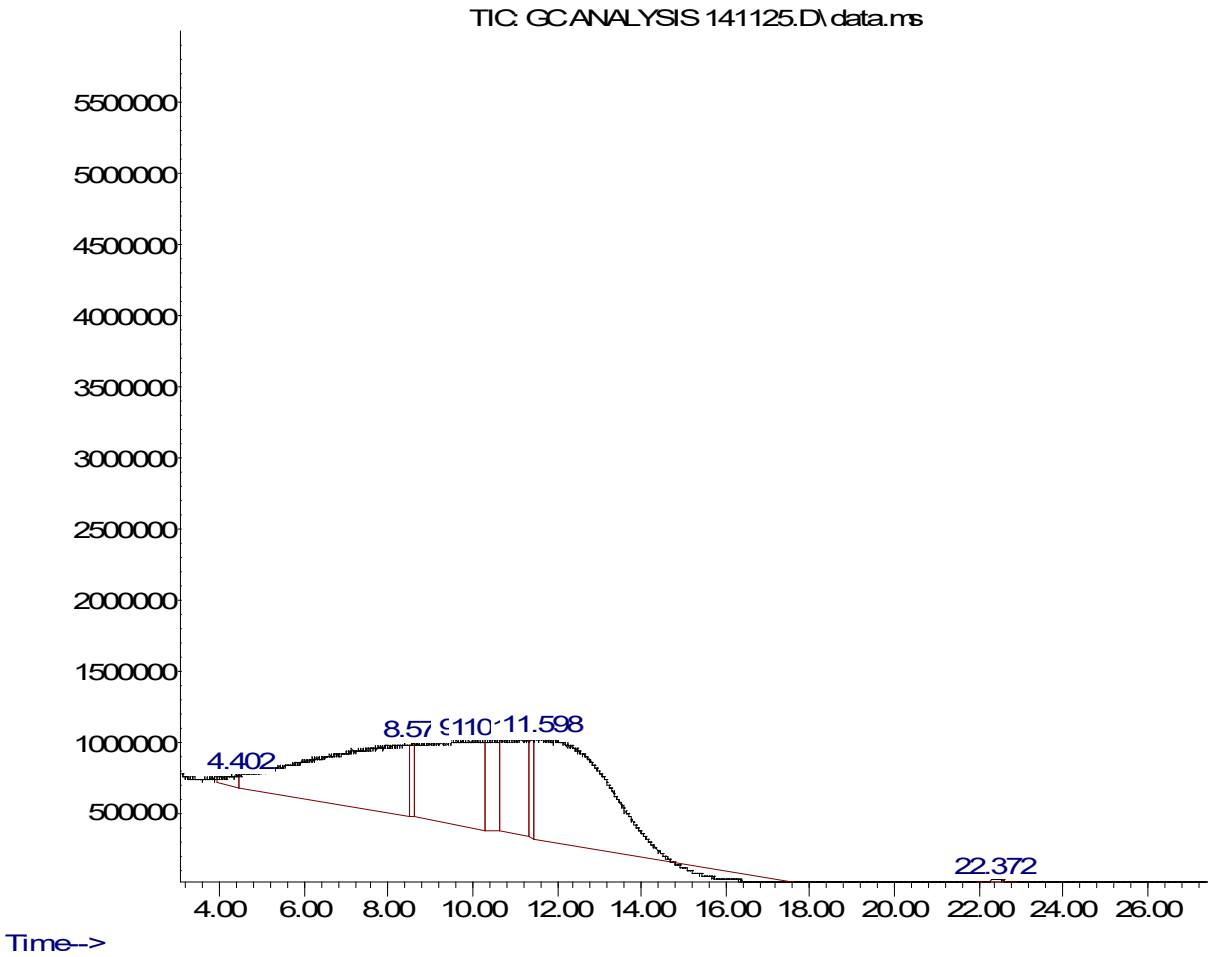

Fig. 6: Chromatogram of raw biogas

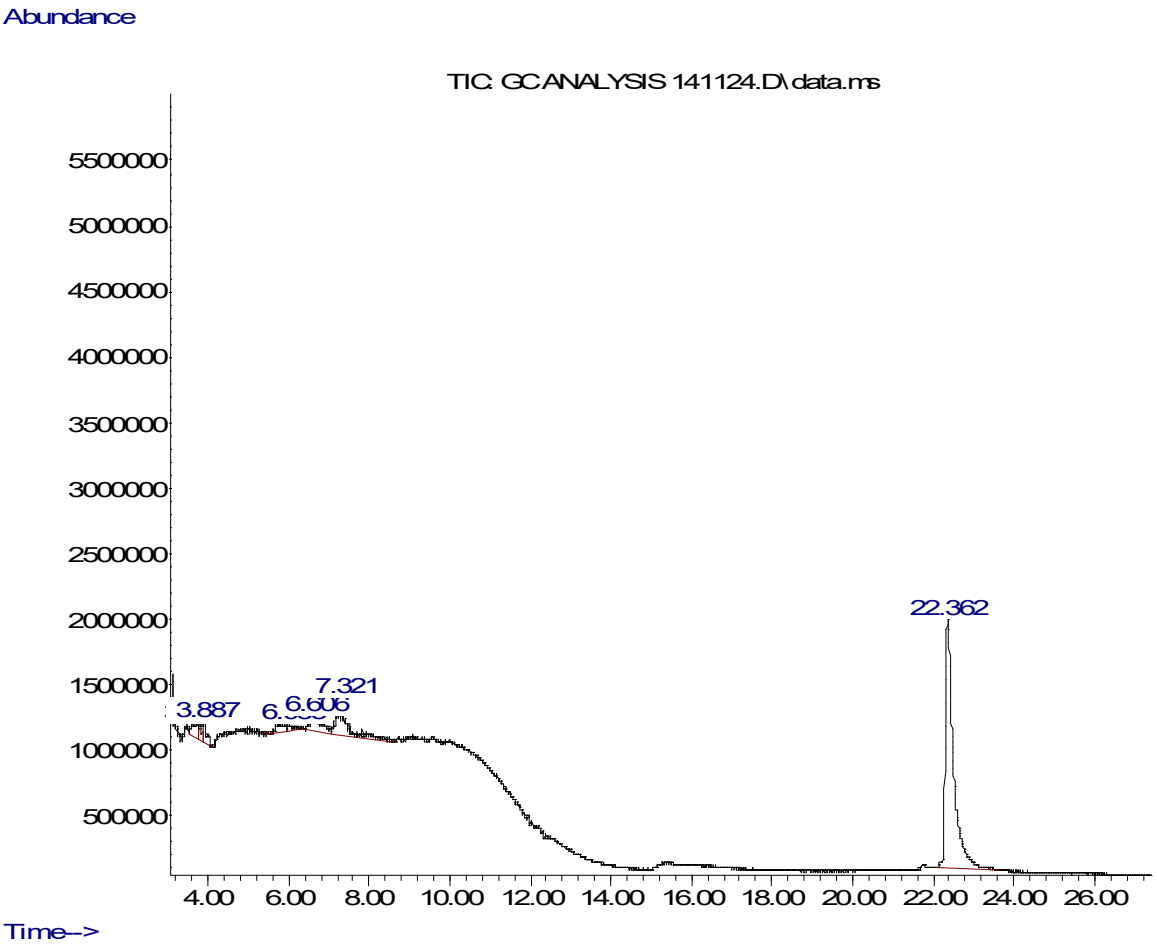

Fig. 7: Chromatogram of purified biogas

In Fig. 7, the chromatogram revealed the components of the purified biogas at the retention time of 4.402, 8.575, 9.910, 10.681, 11.598, and 22.374 minutes respectively. The GC spectrum of the purified gas shows a clearer peak and the disappearance of some peaks in comparison with the raw biogas. According to Remko, (2011), the retention time for methane from biogas analysis is 22.36 minutes whereas the area is 1575957. This finding correlate with the values shown in Fig. 7 above (RT =22.362 minutes).

4.0 Conclusion

Biogas was successfully produced from the co-digestion of cow dung and kitchen waste in the 20-litre digester. Biogas yield and corresponding methane content in it was enhanced by co-digestion of energy crop (kitchen waste) with organic waste (cow dung). Purification of the gas was carried out using cheaply available alkaline. The raw biogas and the purified gas were analysed using GC and IR- spectrometer. The GC result showed a significant difference in chemical composition of the raw gas and purified gas which indicate high efficiency of the four chemicals used for the purification/upgrading of the biogas. Thus, active charcoal might have played a significant role in removing volatile organic compounds (VOCs) from the raw gas. As such, biogas can be purified very easily using chemical scrubbing and activated charcoal method which are readily available and affordable. As such, it is potentially feasible to be utilised as fuel for automobile engine, injected into natural gas grid, or compressed into a cooking gas cylinder for rudimental purpose.

5.0 References

Alghoul, O. El-Hassan, Z., Ramadan, M. & Olabi, A. G. (2019). Experimental investigation on the

production of biogas from waste food. Energy Sources, Part A: Recovery, utilization and Environmental Effects, 41, 17, doi.org/10.1080/15567036.2018.1549156

ASTM D-1945-03. (2010). Standard Test Method for Analysis of Natural Gas by Gas Chromatoghraphy

Atelge, M.R., Krisa, D., Kumar, G., Eskicioglu, C., Nguyen, D. D., Chang, S. W., atabani, A. E., Al-Muhtaseb, A. H. & Unalan, S. (2018). Biogas Production from Organic Waste: Recent Progress and Perspectives. *Waste Biomass Valor,* 11, pp. 1019–1040. https://doi.org/10.1007/s12649-018-00546-0

Bhuiyan, S. H. (2010) A crisis in governance: Urban solid waste management in Bangladesh. Habitat International, 34(1), 125–133.

Chibueze, U., Okorie, N., Oriaku, O., Isu, J. & Peters, E. (2017). The production of biogas using cow dung and food waste. International Journal of Materials and Chemistry, 7, 2, pp. 21-24.

Brendeløkken, H.W. (2016). *Upgrading Technologies for Biogas Production Plants*. Overview and life cycle cost analysis of available technologies (Master Thesis UiT-The Arctic University of Norway, Department of Engineering and Safety).

Butz, S. (2014*). Energy and Agriculture: Science*, *Environment, and Solutions*. Cengage Learning, United State of America.

Caturwati N.K., Sudrajat A., Permana M. & Haryanto H. (2018). *The flame characteristics of the biogas has produced through the digester method with various starters*. International Conference of Chemistry and Material Science, 299, 1, doi:10.1088/1757-899X/299/1/012091.

Divyang S. & Hemant N. (2015). Low cost biogas purification system for application of biogas as fuel for automobile engines. *International Journal of Innovative Science,Engineering & Technology*,2, 6, pp. 308-312.

Eze, J.I. and Agbo, K.E. (2010). Maximizing the Potentials of Biogas through Upgrading. *American Journal of Scientific and Industrial Research,* 3, 1, pp. 604-609

Fandi, D.S., Willyanto, A., & Michael, S.C T. (2016). Effect of carbon dioxide on Flame Characteristics in Biogas External Premix Combustion. *International Journal of Applied Engineering Research*, 11, 4, pp. 2240-2243

Igboro, S. B. (2011). *Production of biogas and compost from cow dung in Zaria*, Nigeria, unpublished (PhD Dissertation) Presented to the Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria Nigeria.

Ikpi, A N., Simon, V. I. & Tanko, B. (2018). Design and Construction of a Tube Storage Device for Biogas Using Motorized Compressor. International *Journal of Science and Qualitative Analysis* 4, 1, pp. 20-26

Konrad, Odorico, Koch, Fabio F., Lumi, Marluce, Tonetto, Jaqueline F., & Bezama, Alberto. (2014). Potential of biogas production from swine manure supplemented with glycerine waste. *Engenharia Agrícola*, *34*, 5, pp. 844-853.

Kumar, A., Mandal, B. & Sharma A. (2015). *Advancement in biogas digester*. Available Online at https://www.researchgate.net/publication /275273428 (date visited 21/1/2020)

Lebunu, H.U.W.A., Jayantha, W. M. & Tharushi, I.S. (2019). Global Research on Carbon Emissions: A Scientometric Review. *Sustainability*, 11, 3972; doi:10.3390/su11143972

Letcher, T. & Vallero, D. (2011). *Waste: A handbook for management*. Burlington M.A Academic Press

Lin, Y., Wang, D., Liang, J., & Li, G. (2012). *Mesophilic anaerobic co-digestion of pulp and paper sludge and food waste for methane production in a fed-batch basis. In Environmental Technology*. Taylor and Francis. pp. 2627-2633.

Morales-Polo, C., Cledera-Castro, M. D. & Soria, B. Y. M. (2019). Biogas production from vegetable and fruit markets waste-Compositional and batch characterization. *Sustainability*, 11, 6790; doi:10.3390/su11236790.

Muthu, D., Venkatasubramanian, C., Ramakrishnam, K. & Sasidhar, J. (2017). Production of Biogas from wastes blended with cow dung for electricity generation-A case study *IOP Conference Series: Earth and Environmental Sciences*,

80 012055, doi :10.1088/1755-1315/80/1/012055.

Masse, D. I., Talbot, G., & Gilbert, Y. (2012). *A scientific review of the agronomic, environmental and social benefits of anaerobic digestion*. In D. J. Caruana, & A. E. Olsen (Eds.), Anaerobic Digestions (pp. 109-131). New York: Nova Science Publishers.

Nasir, I. M., Ghazi, T. I. M. & Omar, R. (2012). Production of biogas from solid organic wastes through anaerobic digestion: A review. *Applied Microbiology and Biotechnology*, 95, 2, 321-329

Ossai, O. S. (2012). E*valuation of gasoline generator modified for biogas utilization*. (MasterThesis University of Nigeria, Nsukka).

Ranade, D. R., Yeole, T. Y. & Godbole, S. H. (1987). Production of biogas from market waste. *Biomass*, 13, 3, pp. 147-153.

Remko V. L. (2011). Analysis of Biogas using the Agilent 490 Micro GC Analyser. Agilent Technologie Inc. Middleburge the Neitherlands. 5990-9508EN, pp. 1-8

Santos, M., Grande, C., & Rodrigues, A. (2013). Dynamic study of the pressure swing adsorption process for biogas upgrading and its responses to feed disturbances. *Industrial & Engineering Chemistry Research,* 52(15), pp. 5445-5454.

Siwatt P., (2014). FTIR Spectra of Organic Functional Group Compositions in PM2.5 Collected at Chiang-Mai City, Thailand during the Haze Episode in March 2012. Journal of Applied Sciences, 14, pp. 2967-2977.

Wade, J., (2003). L.G. *Organic chemistry*, Pearson Education Inc. Sydney, 5th ed, pp. 123-220

Sridhar M.K.C., & Hammed T.B. (2014). Turning Waste to Wealth in Nigeria: An Overview. Journal of Human Ecology, 46, 2, pp. 195-203.

Willyanto, A. (2017). Behaviour of biogas containing nitrogen on flammability limits and laminar burning velocities. *International Journal of Renewable Energy Research*. 7(1), pp. 305-310.

Zamanzadeh, M., Hagen, L. H., Svensson, K. Linjordet, R. & Horn, S. J. (2017). Biogas production from food waste via co-digestion and digestion- effects on performance and microbial ecology. *Scientific Report*, 7, 7664, doi.org/10.1038/s41598-017-15784-w