International Journal of Sustainable and Green Energy
2015; 4(3): 66-72
Published online April 8, 2015 (http://www.sciencepublishinggroup.com/j/ijrse)
doi: 10.11648/j.ijrse.20150403.11

Enhancement of Biogas Yield from Cow Dung and Rice Husk Using Guano as Nitrogen Source

P. A. Nwofe*, P. E. Agbo

Division of Materials Science and Renewable Energy, Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria

Email address:
patricknwofe@gmail.com (P. A. Nwofe), ekumaagbo@gmail.com (P. E. Agbo)

To cite this article:
P. A. Nwofe, P. E. Agbo. Enhancement of Biogas Yield from Cow Dung and Rice Husk Using Guano as Nitrogen Source. *International Journal of Sustainable and Green Energy*. Vol. 4, No. 3, 2015, pp. 66-72. doi: 10.11648/j.ijrse.20150403.11

Abstract: The study reports on the influence of nitrogen source on the biogas yield from cow (N'Dama) dung and rice husk. The digester performance for both feedstocks were evaluated using standard parameters such as; initial PH, water dilution, nitrogen source (guano and poultry droppings) and heavy metals. The source of innoculum used was cow rumen fluid. The result show that for feedstock to water dilution ratio of 1:6 w/v and initial pH of 7.0, the maximum biogas yield for rice husk was 430 mL/day and 350 mL/day for cow dung. The heavy metals (Ni^{2+} and Zn^{2+}) increased the biogas yield while Fe^{2+} (100 ppm) shows no effect. Addition of guano results in maximum production rate of 85 mL/day and 60 mL/day in rice husk and cow dung respectively. The use of guano indicates more biogas production rate in both feedstocks compared to poultry droppings.

Keywords: Cow Dung, Biogas, Guano, Poultry Droppings, Rice Husk

1. Introduction

Renewable energy technologies are currently competing favourably in the energy sector, all geared toward achieving a more sustainable and efficient energy use. Amongst other renewable sources: solar, hydro, geothermal, wind and biomass, biomass is amongst the most vastly explored in terms of research and applications both in the developed and in under-developed countries. It is a common knowledge that fossil fuels-based conventional grid extension constitutes the major centralised power systems from urban areas to rural areas in most under-developed countries. A scenario that is not only capital intensive but also economically unrealistic in most cases. It has been established that more than a quarter of the human population experiences an energy crisis, especially those living in the rural areas of developing countries such as Nigeria [1, 2]. Biomass is generally considered as a suitable alternative to energy from fossil fuels since it can be easily converted to other forms of energy such as biogas and biofuels [3, 4]. It has been reported that Nigeria has an installed capacity of 8,425 MW of electricity but the available capacity is only about 50% of installed capacity [5]. In Nigeria, energy conservation and energy efficiency is strongly needed, thus renewable energy technologies will be essential to the solution and are likely to play an increasingly important role for providing enhanced energy access, reduced over-dependence on fossil fuels, and to help Nigeria meet her vision 20-20-20 clean energy program. Privatisation of PHCN (Power Holding Company of Nigeria) has made many States in Nigeria to be pursuing other source of energy vigorously and Ebonyi State is playing an active role in that direction. Energy from biomass will play a significant role in that Nigeria environment is largely polluted with huge amount of wastes due to rapid urbanisation and poor waste management practices [6-8].

Ebonyi State is popularly known for rice production (Abakaliki rice) in Nigeria and thus has large reserves of rice husks from rice mills which are randomly and strategically located in various towns. These large reserves of rice husks are only utilised as cooking fuels (on a low scale) and source of income for some poor rural dwellers who scavenge those rice husk hills to earn a living. Waste from agricultural, municipal, industrial and household are also common in the study area but these wastes are not presently utilised in a sustainable manner [8]. It has been shown that about 227,500 tons of fresh animal wastes is produced on daily basis in Nigeria [9], implying that Nigeria can produce 6.8 million m^3 gas/day since 1kg of fresh animal wastes yields up to 0.03 m^3 gas. Ogwueleka [10] noted that the waste density of municipal solid waste in Nigeria ranged from 280 to 370 kg/m^3 with the waste generation rates in the range 0.44 to 0.66 kg/capita/day. The generation rate of solid waste in the capital cities of some South-east States of Nigeria (Ebonyi and Imo) is in the range 9.580 to 9.74 x 10^{-3} m^3 [6, 11]. Biogas production from wastes is commonly achieved through anaerobic digestion. Biogas can be utilised as fuels both in low (household, village, community) and large scale (industry) or as fertilisers [12-15]. The use of suitable nitrogen supplement or other parameters to enhance biogas yield has been a subject of research for years. Some authors [16, 17] have used different supplement/parameters in this regard.

This paper investigates the use of locally available and abundant wastes to produce biogas using anaerobic digestion. It also reports on the effect of different parameters (initial PH, water dilution, guano and poultry droppings, heavy metal effect) on the biogas yield and it was observed that the use of guano (bat droppings) enhanced biogas production substantially.

2. Materials and Methods

2.1. Feed Materials

The feed materials were a batch of cow dung and rice husk. The cow dung was sourced locally from cow farms, and the rice husk from Abakaliki Rice Mill Industry, Ebonyi State, Nigeria. The cow dung from N'dama species was used because of its availability compared to other species in the study area. Fig. 1 gives a picture of a typical rice husk hill from Abakaliki rice mill industry. The digester feed included a batch of cow dung and rice husk. Each of these was dried using open sun-baking and then carefully stored in a stoppered polyethylene container. In order to ensure efficient stabilisation of the wastes during anaerobic digestion, innoculum obtained from the rumen of cows slaughtered at Abakaliki main market abattoir was used. The micro-organisms were maintained in an anaerobic environment by straining the innoculum in cheesecloth and then stored in an airtight container. The tip of the digesters was sealed off with clip/cello-tape in order to maintain complete anaerobic condition during the anaerobic digestion for the cow dung and rice husk respectively.

Figure 1. *Picture of a typical rice husk hill in Abakaliki rice mill.*

2.2. Experimental Set-up for the Anaerobic Digestions

Fig. 2 gives the experimental set-up for anaerobic digestion of cow dung (CD) and rice husk (RH). As shown in Fig. 2, each set-up included 1.5 L bottle that served as the anaerobic digester, an inverted 50 mL graduated burette containing acidified water as the biogas collector, and a rubber container which was used to collect the water discharged from the biogas collector. A rubber pipe was used to convey the gas produced in the digester to the collector. The anaerobic digestion was maintained in the mesophilic range in that the room temperature was 31±1°C [18-21]. It has been reported that stratification can lower the production rate of biogas [22, 23], thus this was avoided by mixing each digester once daily for 30 days. The water displacement method used in [24] was utilised in recording the biogas production rate for each anaerobic digester.

Figure 2. *Experimental set-up.*

2.3. Initial pH and Water Dilution

The buffer solutions: citrate buffer of pH 4, phosphate buffer of pH 7, and borax buffer of pH 10 were used to buffer the biogas digesters containing the feedstock. This was done to investigate the impact of the initial pH on the biogas production rate. A 55 mL cow rumen innoculum was added in each case to induce the digestion. A 40 g of feeds each of cow dung and rice husks were mounted in 1.5 L conical flasks, a total of ten stands (five stand for CD and RH respectively). The feedstock to water ratio of 1:2, 1:4, 1:6, 1:8, 1:10 (w/v), were created by moistening each case with water whose volume is in the range 250-450 mL. The fermentation temperature was maintained as before (31±1°C) with a hydraulic retention time (HRT) of 30 days. The same volume of cow rumen innoculum was introduced in each digester and anaerobic condition was ensured by sealing the tip of the flask appropriately. The control experiment had no water included in the digester for the cow dung and rice husk respectively.

2.4. Nitrogen Sources and Trace Metals

A 100 g of each feedstock (CD and RH) was included in conical asks and then mixed with varying quantities of nitrogen sources (poultry droppings and guano). The poultry droppings were sourced from poultry farms while the bat droppings were obtained from aged-buildings roofed with corrugated iron sheets in the rural areas of Ebonyi State. The controls had the same quantity of feedstock without nitrogen source. A feed to poultry droppings/guano ratio of 2.5:1 (w/w) was formed by mixing a 100 g of CD and RH respectively with 40g of poultry droppings/guano in different digesters. The fermentation process in each case was induced by adding 350 mL of water to the same volume of cow rumen as before. The hydraulic retention time was 30 days while the incubation temperature was maintained at 31±1°C.

Concentrations of Fe_3SO_4, $ZnSO_4$ and $NiCl_2$ in the range 40-250 ppm were added to each digester containing 55 g of CD and RH respectively, to investigate the effect of the heavy metal on the biogas production rate. In particular, 250 mL of each solution was added to the digesters. The control in each case had 250 mL of water included only. Fermentation was induced by innoculating each digester with a 55 mL of freshly strained cow rumen liquor.

2.5. Data Acquisition and Analysis

In the experiment, each set of data was taken in quadruplicates and the average was used for the analysis. The analysis was done using the Origin Pro 8 software (trial version).

3. Results and Discussion

3.1. Effect of Initial pH and Water Dilution on Biogas Yield

It is generally known that pH plays a substantial role in the biogas yield under different conditions. This is because the activities of various microbes depend strongly on the pH of the medium amongst other factors. The best pH values in biogas production is in the range 6.5-7.5 [25, 26], though some authors have reported pH values in the range 7.6-8 [27-29]. In the literature, there are varying reports on the effect of pH on the biogas yield involving same or different feedstocks. Result obtained in this study indicate that a pH of 7 gave the best yield of biogas. This value is in agreement with the reports of other authors [16, 27, 28, 30-37] as shown on Table 1.

Table 1. *Literature of the effect of pH on biogas production*

Feedstock	Initial pH	Biogas yield	Ref
Bioethanol waste	6 - 8	increase	[27]
Chicken droppings	7.0	increase	[28]
Chicken droppings	7.2	decrease	[28]
Cow dung	7.0	increase	[16]
Rice straw	6.9 - 7.28	increase	[30]
Rice straw	5.0-5.5	decrease	[30]
Rice husks and cow dung	7.0	increase	This study
Coal	8.0	increase	[31]
Pig manure and maize silage	8.0	increase	[32]
Apple waste with swine manure	7.81 – 7.85	increase	[33]
Cow manure	7.3 – 7.6	decrease	[34]
Saccharina japonica ethanol fermentation	8.0	increase	[35]
Diary manure with three crop residue	5.25 – 6.80	decrease	[36]
Raw and detoxified mahua seed cake	5.9 – 7.2	decrease	[37]

Figs. 3 and 4 give the effect of water dilution on the biogas production rates for rice husk and cow dung respectively. The feed to water dilution ratios of 1:2, 1:4, 1:6, 1:8 and 1:10 w/v all yielded more biogas than the control for the cow dung and rice husk. The maximum biogas production rates for rice husk were observed to be 42, 148, 193, 148 and 55 mL/day respectively at day two. However for cow dung, a maximum biogas production rate of 35 mL/day and 60 mL/day were observed at day two for dilution ratios of 1:2 and 1:10 w/v. On day four, 95 mL/day and 130 mL/day for dilution ratios of 1:4 and 1:6 w/v were observed. The decrease of biogas yield observed in the case of rice husk at lower (1:2 w/v) and higher (1:10 w/v) water dilution ratios could be due to a reduction in the cluster formation of the necessary bacteria needed for biogas production. The variation in days at which maximum biogas yield was observed for the cow dung and rice husk was attributed to the difference in the C/N (carbon/nitrogen) ratio of the feedstocks. Similar behaviour has been observed by other authors [17]. The maximum cumulative biogas yield occurred at a feed to water ratio of 1:6 w/v as shown on Fig. 5.

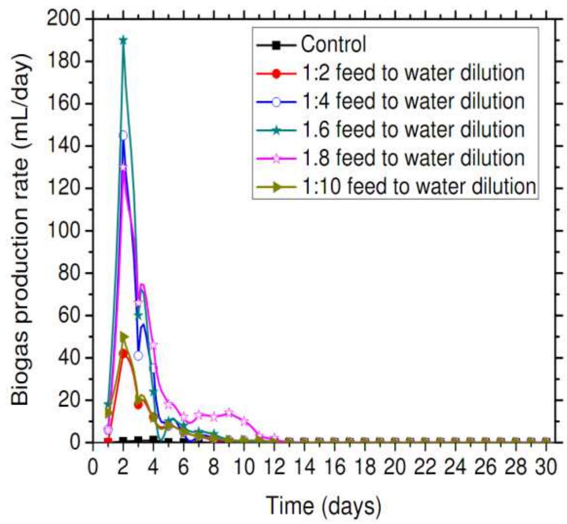

Figure 3. *Biogas production rate for different feed to water dilution ratios (rice husk).*

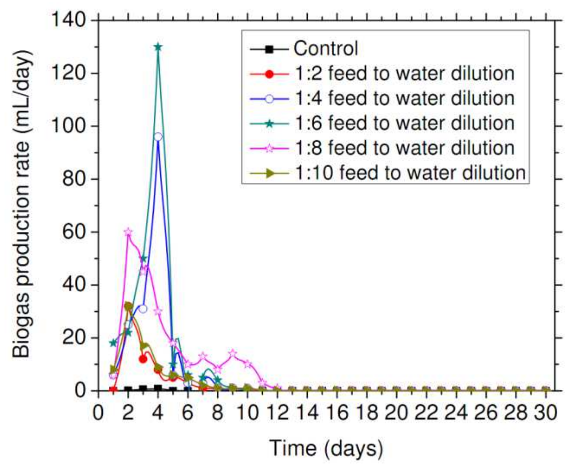

Figure 4. *Biogas production rate for different feed to water dilution ratios (cow dung).*

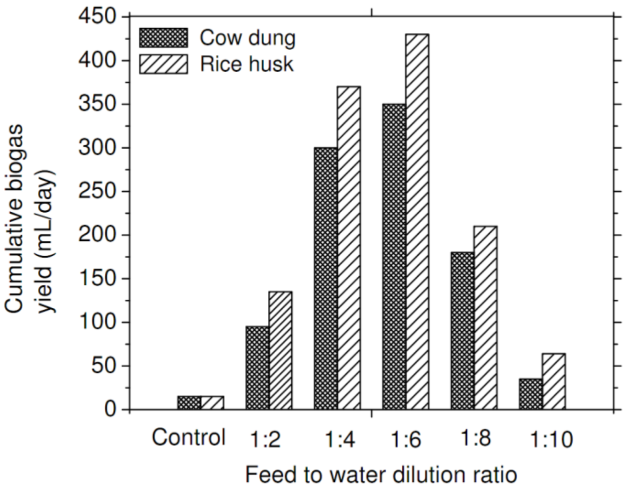

Figure 5. *Cumulative biogas yield for different feed to water dilution ratios.*

3.2. Effect of Nitrogen Source and Trace Metal on Biogas Yield

Fig. 6 gives the effect of nitrogen source on biogas production rate while Fig. 7 gives the cumulative biogas yield. As shown on Fig. 6, the biogas production rate peaked up in both cases compared to the control. A maximum biogas production rate of 85 mL/day and 60 mL/day were observed for the guano supplement in RH and CD respectively. The biogas production rate dropped to 50 mL/day and 40 mL/day for RH and CD respectively when poultry droppings was used as the nitrogen supplement. This could be attributed to a better balance of C:N ratio from the bat droppings. Ahmadu et al. [38] and Ojolo et al. [39] noted that the organic matter content of poultry wastes is a factor that affects the digestion environment and the microbial habitat, hence this could also be responsible for the lower yield observed for the poultry droppings supplement in this study. Table 2 gives the literature of the effect of nitrogen supplement on the biogas yield for same or different feedstocks.

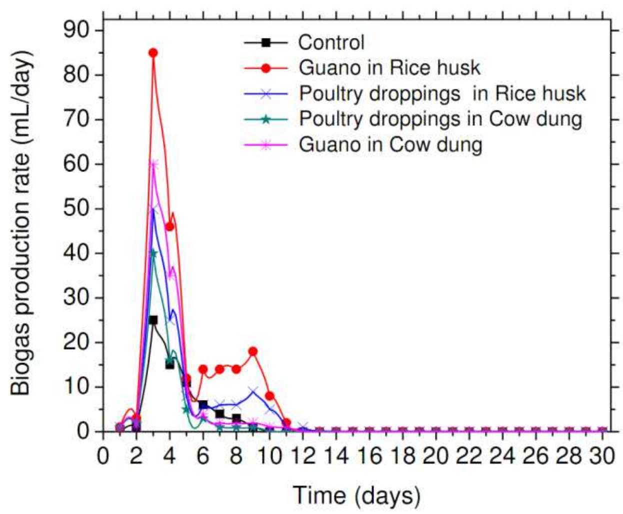

Figure 6. *Influence of nitrogen source on biogas yield.*

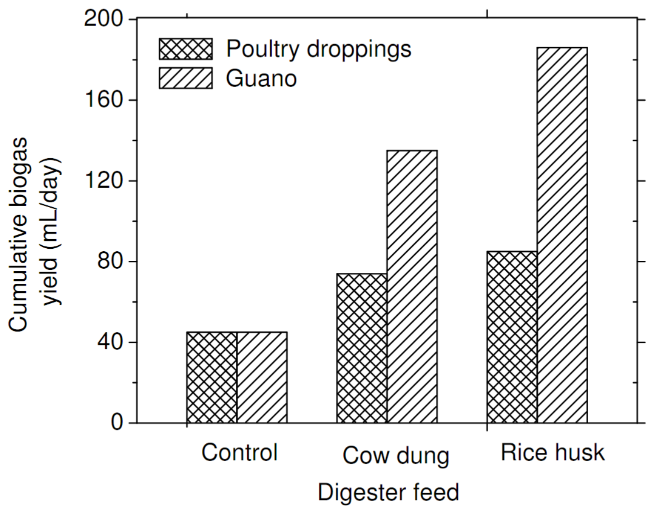

Figure 7. *Influence of nitrogen source on digester performance.*

Trace metals are known to affect the yield of biogas independent of the feedstock. This is because of their effect on the microbial contents of the digester during the anaerobic digestion [47-49]. Demirel and Scherer [50] argued that there is no direct formula for optimum composition of trace metals needed for maximum biogas production. Our result shows that for rice husk, Ni^{2+} (100 ppm) gave 300 mL/day while Zn^{2+} (100 ppm) gave 110 mL/day. For cow dung, Ni^{2+} gave 30 mL/day while Zn^{2+} gave 74 mL/day. No significant effect was observed with Fe^{2+} in both RH and CD respectively. Table 3 gives the effect of trace metals on the digester performance/biogas yield for different/same or different feedstock according to the literature.

Table 2. *Literature of the effect of Nitrogen source on biogas digester*

Feedstock	Nitrogen source	Biogas yield	Ref
Chemical source	not given	not given	[40]
Rice husks	poultry droppings	increase	[41]
Dairy cattle manure	urea	decrease/increase	[42]
Rice straw	urea	increase	[43]
Boiled rice	human urine	increase	[44]
Rice	poultry droppings	increase	[45]
Rice husks and cow dung	guano and poultry droppings	increase	This study
Cattle dung	brassica compestries	increase	[46]
Rice wastes	poultry droppings	increase	[41]

Table 3. *Literature of the effect of trace metals on biogas production*

Feedstock	Trace metal	Biogas yield	Ref
Molasses silage	trace metal	decrease	[48]
Palm oil mill effluent	Ni and Co	increase	[49]
Food waste	K, Ni, Co, Mo, Se and W	decrease/increase	[51]
Palm oil mill effluent	Fe	no effect	[52]
Food waste	Co, Mo, Ni, Se and W		[53]
Azolla piñata R.Br and Lemna minor L	Cd and Ni	increase	[54]

Municipal waste	Fe, Co and Ni	increase	[55]
Rice husks	Ni^{2+}	increase	This study
Cow dung	Zn^{2+}	increase	This study
Rice husk and cow dung	Fe^{2+}	no effect	This study
Holy Basil (ocmium sanctum)	Se	increase	[56]
Chicken manure	Fe^{2+}	decrease	[57]
Municipal waste	Cd, Cr, Cu, Pb, Ni, and Zn	no effect	[58]
Municipal waste	ash	increase	[58]
Municipal waste	Ni, Co and Fe	increase	[59]
Chicken manure	Trace metals	increase	[60]

4. Conclusion

Locally abundant wastes have been investigated to establish the possibility of utilising them as alternative source of energy, thus the effect of different nitrogen sources (poultry droppings and guano) on the biogas yield from cow dungs from N'dama species and rice husk has been reported. The results show that the use of guano as nitrogen supplement is more promising than poultry droppings. A maximum biogas production rate of 85 mL/day and 60 mL/day were obtained for guano supplement in RH and CD respectively while poultry droppings in both feedstocks gave lower biogas yield. The other parameters: initial PH, water dilution, nitrogen source (guano and poultry droppings) and trace metals also affected the digester performance. Our findings show that a feed to water dilution ratio of 1:6 w/v yielded maximum cumulative biogas of 450 mL/day for RH and 350 mL/day for CD. At initial pH of 7.0 for both feedstocks, Ni^{2+} (100 ppm) for rice husk, and Zn^{2+} (100 ppm) for cow dung gave the best biogas yield while Fe^{2+} show no effect in RH and CD respectively. All the parameters tested increased the biogas yield without affecting the methane content. The findings reported herein could serve as a useful guide for further research to optimise the conditions needed to improve biogas yield from locally available and abundant wastes.

Acknowledgements

Dr P.A. Nwofe and Dr P.E. Agbo would wish to thank the staff of Ishieke Annex, Ebonyi State University, Abakaliki, for permission to use some equipments/chemicals from their laboratory. The authors also thank the staff of Ebonyi State Hatchery, Nkaliki and Rice Mill Industry, Abakaliki for permission to procure the feedstocks (poultry droppings and rice husks).

References

[1] C.E. Nnaji, C.C. Uzoma, and J.O. Chukwu, "The role of renewable energy resources in poverty alleviation and sustainable development in Nigeria", Continental J. Social Sciences, vol. 3, pp. 31 – 37, 2010.

[2] Y.Y Babanyara and U.F. Saleh, "Urbanisation and the Choice of Fuel Wood as a Source of Energy in Nigeria," J. Hum. Ecology, vol. 31(1), pp. 19-26, 2010.

[3] A. Converti , R.P.S Oliveira, B.R. Torres, A. Lodi, and M. Zilli "Biogas production and valorisation by means of a two-step biological process," Bioresource Technology vol. 100(23) pp. 5771-5776, 2009.

[4] C.I. Marrison and E.D. Larson, "A preliminary analysis of the biomass energy production in Africa in 2025 considering projected land needs for food production" Biomass and Bioenergy, vol. 10(5/6), pp. 337-351, 1996.

[5] B. Nnaji, Investment Opportunities in the Nigerian Power Sector. Nigeria Business and Investment Summit, London. July 30, 2012. http://www.newworldnigeria.com/pdf/HMPPowerSectorReformsPresentationBoINOCLondon30JULY2012.ppt, Accessed January 31, 2015.

[6] P.A. Nwofe, "Determination of the Generation rate of solid waste in Abakaliki Metropolis, Ebonyi State, Nigeria", Continental J. Environmental Sciences, vol. 7(2), pp. 1-3, 2013.

[7] N.I. Elom, "Healthcare solid wastes management protocols in Nigeria and implications for human health risk A review", Continental J. Environmental Sciences, vol. 7(1), pp. 11-19, 2013.

[8] P.A. Nwofe, "Waste management and environmental sustainability: A case study of selected cities in Ebonyi State," Continental J. Environmental Sciences, vol. 7(1), pp. 20-28, 2013.

[9] O.C. Eneh, "Managing Nigeria's environment: the unresolved issues," J Environ Sci Technol, vol. 4(3), pp. 250-263, 2011.

[10] Tch. Ogwueleka, "Municipial solid waste characteristics and management in Nigeria", Iran. J. Environ. Health. Sci. Eng. Vol. 6(3), pp. 173-180, 2009.

[11] H.U. Nwoke, "Generation rate of solid wastes in Owerri metropolis, Imo State Nigeria," Continental J. Environmental Sciences, vol. 7(1), pp. 8-10, 2013.

[12] J. Abubaker, H. Cederlund, V. Arthurson, and M. Pell, "Bacterial community structure and microbial activity in different soils amended with biogas residue and cattle slurry," Applied Soil Ecology, vol. 72, pp. 171-180, 2013.

[13] P. Weiland, "Biogas production: Current state and perspectives", Appl Microbiol Biotechnol, vol. 85(4), pp. 849-860, 2010.

[14] T. Bond and M.R. Templeton, "History and future of domestic biogas plants in the developing world", Energy Sustain Dev, vol. 15(4), pp. 347-354, 2011.

[15] W. Zhong, Z. Zhang, W. Qiao, P. Fu, and M. Liu, "Comparison and chemical pretreatment of corn straw for biogas production by anaerobic digestion," Renewable Energy vol. 36, pp. 1875-1879, 2011.

[16] A.S. Sambo, B. Garba, and B.G. Danshehu, "Effect of some operating parameters on biogas production rate," Renewable Energy, vol. 6(3), pp. 343-344, 1995.

[17] C.E.C. Fernando, "Factors which affect biogas production", Nigerian Journal of Solar Energy, vol. 4, pp. 150-154, 1985.

[18] K.J. Chae, Jang Am, S.K. Yim, and S. In Kim, "The effects of digestion temperature and temperature shock on the biogas yields from the mesophilic anaerobic digestion of swine manure", Bioresource Technology, vol. 99(1), pp. 1-6, 2008.

[19] P. Bolzonella, P. Battistonic, and F. Cecchi, "Mesophilic anaerobic digestion of waste activated sludge: Influence of the solid retention time in the wastewater treatment process" Process Biochemistry, vol. 40, pp. 1453-1460, 2005.

[20] A. Bonmat'i and X. Flotats, "Air stripping of ammonia from pig slurry: characterisation and feasibility as a pre- or post-treatment to mesophilic anaerobic digestion," Waste Management, vol. 23(3), pp. 261-272, 2003.

[21] C. Gallert and J. Winter, "Mesophilic and thermophilic anaerobic digestion of source-sorted organic wastes: effect of ammonia on glucose degradation and methane production" Appl Microbiol Bitechnol, vol. 48, pp. 405-410, 1997.

[22] M. Saidu, A. Yuzir, M.R. Salim, S. Salmiati, Azman, and N. Abdullah, "Influence of palm oil mill effluent as inoculum on anaerobic digestion of cattle manure for biogas production," Bioresource Technology, vol. 141, pp. 174-176, 2013.

[23] Zhu J, Zheng Y, Xu F, Li, Y. Solid-state anaerobic co-digestion of hay and soybean processing waste for biogas production. Bioresource Technol. 2014; 15:240-247.

[24] Chen G, Zheng Z, Yang S, Fang C, Zuo X, Luo, Y. Experimental co-digestion of corn stalk and vermicompost to improve biogas production. Waste Management 2010; 30:1834-1840.

[25] Tong Z, Linlin L, Zilin S, Guangxin R, Yongzhong F, Xinhui H, Gaihe Y. Biogas Production by Co-Digestion of Goat Manure with Three Crop Residues. PLoS One 2013;8(6):e66845.

[26] Chandra R. Studies on production of enriched biogas using jatropha and pongamia de-oiled seed cakes and its utilisation in I.C. Engines. PhD thesis 2009; Centre for Rural Development and Technology, IIT Delhi.

[27] Budiyono, Igbal S, Siswo S. Biogas production from bioethanol waste: the effect of pH and urea addition to biogas production rate. Waste Tech 2013;1(1):1-5.

[28] Oyewole OA. Biogas production from chicken droppings. Science World Journal 2010;5(4):11-14.

[29] Parkin G, Owen F. Fundamentals of anaerobic digestion of waste water sludges. Journal of Environmental Engineering 1986;112(5):867-920.

[30] Ye J, Li D, Sun Y, Wang G, Yuan Z, Zhen F, Wang Y. Improved biogas production from rice straw by co-digestion with kitchen waste and pig manure. Waste Management 2013;33:2653-2658.

[31] Gupta P, Gupta A. Biogas production from coal via anaerobic fermentation. Fuel 2014;118:238-242.

[32] Strik DPBTB, Domnanovich P, Holubar P. A pH-based control of ammonia in biogas during anaerobic digestion of artificial pig manure and maize silage. Process Biochemistry 2006;41:1235-1238.

[33] Kafle GK, Kim SH. Anaerobic treatment of apple waste with swine manure for biogas production: Batch and continuous operation. Applied Energy 2013;103:61-72.

[34] Sánchez-Hernández EP, Weiland P, Borja R. The effect of biogas sparging on cow manure characteristics and its subsequent anaerobic biodegradation. International Biodeteroriation and Degradation 2013;83:10-16.

[35] S.M. Lee and J.H. Lee, "Effect of sludge treatment on biogas production from Saccharina japonica ethanol fermentation by-products", Journal of Industrial and Engineering Chemistry, vol. 21, pp. 711-716, 2015.

[36] Li J, Wei L, Duan Q, Hu G, Zhang G. Semi-continuous anaerobic co-digestion of dairy manure with three crop residues for biogas production. Bioresource Technol. 2014;156:307-313.

[37] Gupta A, Kumar A, Sharma S, Vijay VK. Comparative evaluation of raw and detoxified mahua seed cake for biogas production. Applied Energy 2013;102:1514-1521.

[38] Ahmadu TO, Folayan CO, Yawas DS. Comparative performance of cow dung and chicken droppings for biogas production. Nig. J. Eng. 2009;16(1):154-164.

[39] Ojolo SJ, Dinrifo RR, Yadesuyi KB. Comparative study of biogas from five substrates. Advance Materials Research Journal 2007;18(10):519-525.

[40] Wagner AO, Hohlbrugger P, Lins P, Illmer P. Effects of different nitrogen sources on the biogas production a lab-scale investigation. Microbiological Research 2012;167(10):630-636.

[41] Okeh CO, Onwosi CO, Odibo FJC. Biogas production from rice husks generated from various rice mills in Ebonyi State, Nigeria. Renewable Energy 2014;64:204-208.

[42] Sterling Jr MC, Lacey RE, Engler CR, Ricke SC. Effects of ammonia nitrogen on H_2 and CH_4 production during anaerobic digestion of dairy cattle manure. Bioresource Tchnol. 2001;77(1):9-18

[43] Zhang R, Zhang Z. Biogasification of rice straw with an anaerobic phased solids digester system. Bioresource Technology 1999;68(3):235-245.

[44] Sau SK, Manna TK, Giri A, Nnandi PK. Effect of Human Urine during Production of Methane from Boiled Rice. International Journal of Science and Research 2013;2(10):60-64.

[45] Ganiyu OT, Oloke JK. Effects of organic Nitrogen and Carbon supplementation on biomethanation of rice bran. Fountain Journal of Natural and Applied Sciences 2012;1(1):25-30.

[46] Satyanarayana S, Murkute P, Ramakant. Biogas production enhancement by Brassica compestries amendment in cattle dung digesters. Biomass and Bioenergy 2008;32:210 215.

[47] Mudhoo A, Kumar S. Effects of heavy metals as stress factors on anaerobic digestion processes and biogas production from biomass. Int. J. Environ. Sci. Technol. 2013;10:1383-1398.

[48] Espinosa A, Rosas R, Ilangovan K, Noyola A. Effect of trace metals on the anaerobic degradation of volatile fatty acids in molasses stillage. Water Science and Technology 1995;32(12):121-129.

[49] Matseh I. Effect of Ni and Co as Trace Metals on Digestion Performance and Biogas Produced from The Fermentation of Palm Oil Mill Effluent. International Journal of Waste Resources 2012;2(2):16-19.

[50] Demirel B, Scherer P. Trace elements requirements of agricultural biogas digesters during biogas conversion of renewable biomass to methane. Biomass and Bioenergy 2011;35:992-998.

[51] Faachin V, Cavinato C, Pavan P, Bolzonella D. Batch and continuous Mesophilic Anaerobic Digestion of Food Waste:Effect of Trace Elements Supplementation. Chemical Engineering Transact-ions 2013;32:457-462.

[52] Irvan. The Effect of Fe Concentration on the Quality and Quantity of Biogas Produced From Fermentation of Palm Oil Mill Effluent. International Journal of Science and Engineering 2012;3(2):35-38.

[53] Facchin V, Cavinato C, Fatone F, Pavan P, Cecchi F, Bolzonella D. Effect of trace element supplementation on the mesophilic anaerobic digestion of foodwaste in batch trials: The influence of inoculum origin. Biochemical Engineering Journal 2013;70:71-77.

[54] Jain SK, Gujral GS, Jha NK, Vasudevan P. Production of biogas from Azolla pinnata R.Br and Lemna minor L.: effect of heavy metal contamination. Bioresoure Technol 1992;41:273-277.

[55] Wanqin Z, Shubiao W, Qianqian L, Renjie D. Trace elements on influence of anaerobic fermentation in biogas projects. Transactions of the Chinese Society of Agricultural Engineering 2013;29(10):1-11.

[56] Swapnavahini K, Sumanth Kumar M, Appala Naidu G. Effect of Selenium on acceleration of biogas and trends of Nitrogen and Phosphorous. International Journal of Innovative Research and Practices 2013;1(7):24-28.

[57] Wanqin Z, Jianbin G, Shubiao W, Renjie D, Jie Z, Qian-qian L, Xin L, Tao L, Changle P, Li C, Baozhi W. Effects of Fe^{2+} on the Anaerobic Digestion of Chicken Manure: A Batch Study. 2012 Third International Conference on Digital Manufacturing & Automation, Guilin, China July 31, 2012 to Aug. 2, 2012, ISBN: 978-1-4673-2217-12012;364-368.

[58] Lo HM. Metals behaviors of MSWI bottom ash co-digested Anaerobically with MSW. Resources, Conservation and Recycling 2005;43(3): 263-280.

[59] Zitomer DH, Johnson CC, Speece RR. Metal Stimulation and Municipal Digester Thermophilic/Mesophilic Activity. Journal of Environmental Engineering 2008:134(1):42-47.

[60] M. Brule, R. Bolduan, S. Seidelt, P. Schlagermann, A. Bott, “Modified batch anaerobic digestion assay for testing efficiencies of trace metal additives to enhance methane production of energy crops,” Environmental Technology vol. 34(13/14), pp. 2047-2058, 2013.