Enhanced Biogas Production From Fresh Elephant Grasses, Using Liquid Extract From Plantain Pseudo Stem

Victor M. Mbachu, Anthony C. Igboanugo, Uchechukwu J. Alukwe , Modestus O. Okwu

Abstract: The purpose of the exploratory research is to ascertain the possibility of improving the quality and quantity of biogas yield from anaerobic digestion of elephant grass (pennisetum purpureum), which has been considered a potential alternative to cow dung, using Liquid extract from plantain (Musa paradisiacal normalis) pseudo stem. The concept of comparative advantage and productive effect of synergy was adopted in trying to obtain biogas production of better yield and quality from the two feedstocks. Liquid extract from plantain pseudo stem; which previously was considered as waste, but recently have been found to have low biogas yield with high methane content; was considered useful as the mixing fluid instead of water. Six digesters were developed using 500ml conical flasks for the experiment with 3 duplicates runs. The first set contained elephant grass and water, the second contained elephant grass and liquid extract from plantain pseudo stem, while the third is loaded with liquid extract from plantain pseudo stem only. The pH of the substrates was improved through partial decomposition prior to digestion. The digesters were then monitored for 36 days, measuring the biogas yield and the ambient temperature. All the trials produced biogas after 3 to 4 days of inoculation as observed and confirmed using flame test. The digesters containing combination of elephant grass and liquid extract from plantain pseudo stem gave the highest yield, as well as the best quality – in terms of methane content. The results from the experiment shows a 45.95% and 33.95% improvement in biogas yield and methane content respectively when the liquid extract from plantain pseudo stem was used to mix the elephant grass instead of water. Although, biogas generation from elephant grass has been widely reported in literature, but at relatively low methane content (43.4 to 64.3%). Hence, it requires more post-production upgrading effort to bring the methane content to the value admissible into internal combustion engine. The findings of this research provides efficient means of improving the methane content of the produced gas to 72.97 ± 3.8 %, using liquid extract from plantain pseudo stem. The research thus found productive use for the liquid extract from plantain pseudo stem, as well as possibility of having better yield from anaerobic digestion of elephant grass. This research is purely original.

Index Terms: Biomass Biodegradation, Elephant grass, Methane Content, Plantain pseudo stem, waste-to-wealth philosophy,

1 INTRODUCTION

Although cow dung and cow manure have been widely used for biogas generation, their efficient utilization has been in farmstead and areas with abundant generation and supply (e.g. India, where the growth rate in the number of cow is far greater than the death or depletion rate.). This is not the case with Nigeria, where the consumption of cow for meat is steadily increasing. Also, with the nomadic method of rearing the animal in Nigeria, the production and availability of cow dung as feedstock for biogas production is highly limited. Whereas grass has been considered viable alternative to cow dung due to its availability in relatively large quantity all year round, the biogas production rate from grass (in terms of ml of biogas per gram of grass) and the quality of the produced gas (in terms of methane content) has been an issue of serious concern, when compared to cow dung. Interestingly, liquid extract from plantain pseudo stem has been found to produce very high quality of biogas in terms of methane content, but at low yield rate [19].

- *Mbachu, Victor M., is currently rounding up his PhD degree program in Production engineering in University of Benin, Nigeria, He is aslo a lecturer in Industrial and Production Engineering, Nnamdi Azikiwe University Awka, Nigeria. 08030958571. E-mail: vm.mbachu@unizik.edu.ng*
- *Alukwe, Uchechukwu J.., is currently pursuing a masters degree program in Enviromental Microbiology in Nnamdi Azikiwe University Awka, Nigeria, and a technologist in Pharmaceutical Microbilogy in Nnamdi Azikiwe University Awka, Nigeria. 08060750206. E-mail: uj.alukwe@unizik.edu.ng*
- *Okwu, Modestus O., is currently a postdoctoral fellow in the department of Mechanical and Industrial Engineering, University of Johannesburg South Africa, and a Senior Lecturer in Federal University of Petroleum Resources, Effrum, Delta state, Nigeria. 07037925341. E-mail: okwu.okechukwu@fupre.edu.ng*
- *Anthony C. Igboanugo died while the manuscript is been prepared, and his supervisory role contributed significantly towards the actualization of the research goals. Untill his death, he is a professor in the department of Production Engineering, University of Benin*

The tripartite nature of the biomass sustainability problem demands for systematic investigation on ways of improving; the availability of biomass, the biomass' biogas yield rate, and the quality of biogas produced from the biomass. These constitute the main decision variables in the objective function of grass to electricity sustainability model investigated by one of the authors. Research on biogas design and development has been extensively showcased in literature of Energy sources [3; 7; 11; 14; 16; 21; 22; 23; 25; 28; 36; 38]. Conversely, quite a number of research in this area focused on production of biogas using: Banana peel [10], water hyacinth plant [4; 26; 33]; hybrid waste [2; 6; 18; 33]; water leaf plant [24]; other plant biomass [5; 37] and food waste [39]. Although there exist plethora of research work carried out and reported in literature in the area of enhancing biogas production using co-digestion of biomass of plant origin and that of animal origin. The interesting aspect of this research work is the use of readily available waste resource of same origin – plant, to enhance biogas production from grass. Biogas has been reported to have been produced from different types of grass: Buffalo grass [8]; water hyacinth [29]; Guinea grass [35]; Sudan grass [17] and Elephant grass [20; 32; 35]. According to the reports from the reviewed literature, anaerobic digestion of grasses especially elephant (Napier) grasses produces biogas with methane content of 43.4 to 64.3%. For instance, [32] reported 53% for elephant (Napier) grass; [35] reported that Elephant grass (6% total solid) gave 52.8%; while [20] reported 64.3%. In order to widen the application and improve combustion efficiency of biogas produced from anaerobic digestion of grass, enhancement of its methane content is necessary. This could be done through the pre-digestion, post-digestion or both approaches. While the post-digestion approach involves purification of biogas produced, the pre-digestion method involves the use of various means to

enhance the quality of biogas to be produced. The pre-digestion method seems more efficient and increases the extent to which the biogas can be be further purified. The use of pre-digestion method in improving the quality of biogas produced from grass has been sought via different means: increasing the inoculum-to-substrate ratio up to 1 [1], crushing of the grass and increase in the dilution ratio [13], use of cow rumen fluid as the mixing fluid or as additive [15; 27] and co-digestion. The efficiency of the co-digestion technique is dependent on biogas or bio-methane yield potential of the added feedstock [30], the mixing ratio [9; 31], and the compatibility of the constituents [12; 34].
The success report of [15] on improvement of biogas yield from cow dung by replacing water with cow rumen fluid as the mixing fluid served as clue in this research work. Also considering the teeming availability of plantain trees, the high moisture content (94.79±1.5) in the pseudo stem as well as the high methane content (75.2%) of biogas produced from the liquid extract as reported in [19]; the liquid extract from plantain pseudo stem was considered a potential additive or co-substrate for enhancing biogas quality from the selected base biomass – elephant grass. From the reviewed literature, no such attempt have been made to enhance quality of biogas produced from elephant grass, either as an additive or in form of co-digestion. This research work thus seeks to enhance the conversion of grass to gas, using this readily available but initially considered waste of waste, as the mixing fluid instead of water.

Figure 1. *Preparation of Feedstock from Elephant Grass*

2 MATERIALS AND METHOD

2.1 Sample Collection and Preparation

The plantain pseudo stems were obtained from a nearby mini plantation after harvest at Nibo, in Awka – South local government area of Anambra state in Nigeria. The grass, on the other hand, was harvested from the same neighborhood. The elephant grass was chopped into small strands and then pulverized to produce the feedstock, while the plantain pseudo stem was cut into smaller lumps, pounded and pressed to extract the fluid as shown in Figure 1 and 2 respectively.

Figure 2. *Preparation of Liquid Extra from Plantain Pseudo Stem*

2.2. Physio-chemical Parameters

The following physio-chemical properties were evaluated for the two feedstock sources using the conventional methods and equipment: Nitrogen .Ash content, Moisture Content, Total solid, and Volatile Solid. The obtained values are presented in Table 1

Table 1: *Physiochemical Parameters of the Feedstock*

Feedstock	Moisture Content (%)	Total Solids (%)	Volatile Solid (% of total solid)	Ash Content (% of feedstock)	Nitrogen Content (% of feedstock 0.5g)	Carbon content (% of feedstock 2g)	C/N Ratio (C1M1/N2M2)	pH
Elephant grass leaves	68.40	31.60	94.44	2.000	2.268	10.00	17.64	5.2
Elephant grass stem	72.00	28.00	96.74	0.914				
plantain pseudo stem	94.79	5.21	88.22	0.612	1.036	2.33	10.00	6.6*

* The pH is that of Liquid extract from plantain pseudo stem

Nitrogen Content
The AOAC 1984 method was employed using 0.5gram of the sample. The percentage of Nitrogen content in the sample was computed using equation 1:

$$\text{Nitrogen content } (\%) = (\text{titre value } \times 0.01 \times 14 \times 4) \times 100$$

Ash Content
Vecster furnaces was used at 5000C. The sample was measured out in a crucible of known weight and heated in the furnace until constant weight after ashing. The ash content was computed based on wet matter;

$$\text{ash content } (\%) = \frac{m3 - m1}{m2 - m1} \times 100 \qquad (2)$$

m_1 = mass of the crucible (gram)
m_2 = mass of the substrate and crucible before heating (gram);
m_3 = mass of the substrate and crucible after heating (gram).
Moisture Content
Samples of the biomass were measured out, placed in a Petri dish and dried in a hot air oven to constant weight at 1050C.

The moisture content of the biomass was computed by equation (3)

$$\text{moisture content } (\%) = \frac{\text{m1} - \text{m2}}{\text{m1} - \text{m0}} \times 100 \qquad (3)$$

m_0 = mass of the empty Petri dish (gram)
m_1 = mass of the fresh sample and the dish before drying (gram);
m_2 = mass of the dry sample and the dish after drying (gram).
Total Volatile Solid
This is computed based on wet matter:

$$\text{Total volatile solid } (\%) = \left(\left(\frac{\text{m2} - \text{m3}}{\text{m2} - \text{m1}} \times 100\right)\right) - \text{mc} \qquad (4)$$

m_1 = mass of the crucible (gram)
m_2 = mass of the substrate and crucible before heating (gram);
m_3 = mass of the substrate and crucible after heating (gram).
mc = moisture content of the substrate in percentage of wet matter weight

Total Carbon Content
The wet sample of the feedstock was measured out (2grams) and heated over a Bunsen burner in a foil of known weight until it was charred. The post charring weight of the sample was measured as the total carbon. Thus the total carbon content (%) is given as;

$$\text{Total Carbon Content } (\%) = \frac{(\text{m3} - \text{m1})}{(\text{m2} - \text{m1})} \times 100) \qquad (5)$$

m_1 = mass of the foil (gram)
m_2 = pre heating mass of the substrate and foil (gram);
m_3= post heating (charring) mass of the substrate and foil (gram).
From table 1, it can be deduced that 93.7% of the total solids are volatile. Also, grass in its fresh form have low carbon-nitrogen ratio and will affect digestion efficiency, thus the need to decompose the grass, reducing the nitrogen content as well as improving the pH which was found to be too acidic for methanogenesis.

2.3 Digester Experimental Procedure

An eight(8) experimental runs was designed as shown in the Table 2, to show the interaction between the factors studied. Although based on the design, eight(8) experimental runs was needed, but two experimental runs were stepped down (I.e. W1 and W2 – distilled water), on the bases that distilled water can not produce biogas, since there is no carbon component in it. Therefore, Six (6) experimental runs were developed – elephant grass mixed with water (GW1 and GW2), elephant grass mixed with liquid extract from plantain pseudo stem (GP1 and GP2), and liquid extract from plantain pseudo stem (PE1 and PE2).

Table 2: *Design of the Experiment*

	Elephant Grass	Elephant Grass (duplicate)	CONTROL (stand alone)	
Liquid Extract From Plantain Pseudo Stem	GP1	GP2	PE1	PE2
Distilled Water	GW1	GW2	W1	W2

NB: XY2 is the duplicate of XY1

The digesters were made of 500 ml of conical flask, wrapped in black tape to minimize light penetration. Ease of collection of produced gas was incorporated as shown in Figure 3. The prepared feedstock was allowed for partial quasi aerobic decomposition for about 12 days, in order to improve the pH (especially for grass) to pH of about 8 before introduction into the respective digesters.

Figure 3: *Biogas production and measurement set up*

The content of each digester was inoculated with about 5ml of liquid obtained from digesters already undergoing biogas production, and thereafter monitored for 36 days. The ambient temperature was checked daily, while the gas produced was measured every two days after an initial confirmatory flame test that ascertained biogas production..

2.4 Biogas Parameters Measured

The daily biogas production volume was measured using water displacement method, and the quality of the gas produced analyzed using gas chromatography at Springboard Lab. The ambient temperature was measured daily using general purpose liquid-in - glass thermometer (0 to 1000C).

3 RESULT AND ANALYSIS

The result presented includes the biogas yield, quality of biogas produced and the ambient temperature recorded. The graphical representation of the biogas production throughout the retention period, aside the two to three days pre-production period, is presented in Figure 4.

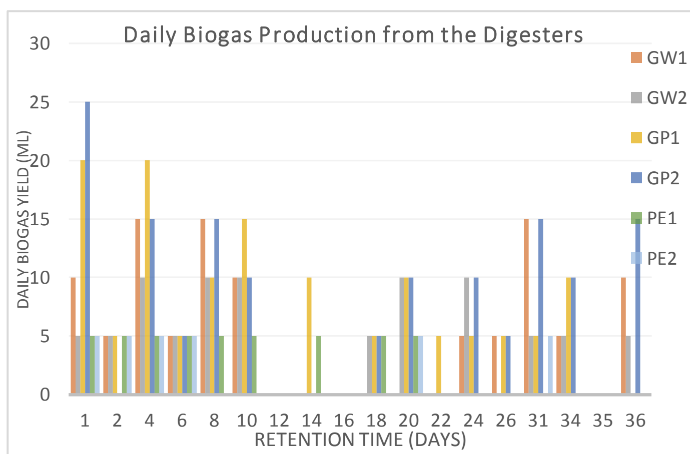

Figure 4: *Biogas Production from the Digesters*

The GP1 and GP2 gave the highest cumulative biogas yield of 130ml and 140 ml respectively for the considered retention time. The biogas yield from PE1 and PE2 were the least, although the quality of the biogas produced from PE1 and PE2 were better than those from GW1 and GW2. Figures 5 and 6 presents the result of the interractions on quantity and quality of the biogas produced.

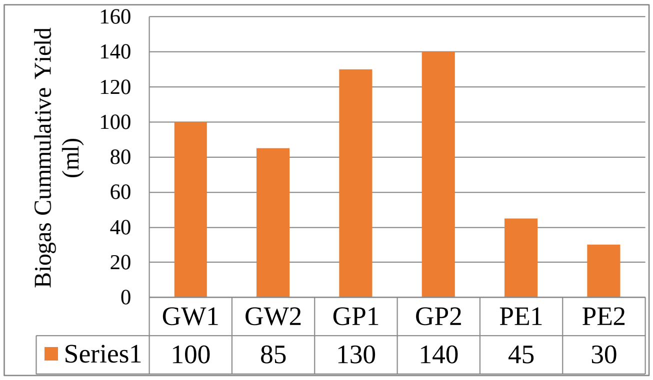

Figure 5: *Comparative Plot of Cumulative Biogas Production from the Digesters*

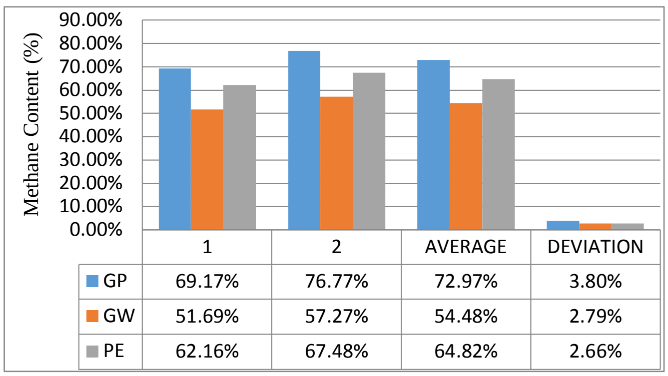

Figure 6: *Methane Content of Samples of Biogas Produced from the Digesters*

The gas chromatography analysis revealed that the biogas produced from the combination of elephant grass and the liquid extract from plantain pseudo stem consistently gave the highest methane content (average of about 73%), see Figure 6.

4 CONCLUSION

Based on the results obtained from the experiment, it is evident that the yield and quality of biogas produced through anaerobic digestion of elephant grass can be improved through the use of liquid extract from pseudo plantain stem instead of water, as the mixing fluid. The biogas yield and quality were improved by 45.95% and 33.95% respectively. Thus, productive use for the liquid extract, which is readily available after harvest, as well as efficient method of enhancing biogas production from elephant grass, was found. Considering the fact that the liquid extract was initially considered as waste even in the use of the pseudo stem for development of composite material, its current productive use in enhancing biogas production becomes a typical case of waste to wealth conversion.

5. REFERENCES

[1] Abu-Dahrieh, J. K., Orozco, A., Ahmad, M., and Rooney, D. (2011). The Potential for Biogas Production from Grass. Jordan International Energy Conference, Amman, 2011.

[2] Adam N., and Shanableh A. (2015). Comparison of biodiesel production from a variety of feedstocks. Proceedings of the Third International Conference on Water, Energy and Environment (ICWEE). p. 362–368.

[3] Ahmadu T.O. Comparative performance of cow dung and chicken droppings for biogas production, M.Sc Thesis Submitted to the Department of Mechanical Engineering, Ahmadu Bello University, Zaria; 2009.

[4] Almoustapha, O., Kenfack, S., and Millogo-Rasolodimby, J., (2009). Biogas production using water hyacinths to meet collective energy needs in a sahelian country. Field Action Sci. Rep., 73–77.

[5] Alvarez, J.A., Otero, L., and Lema, J.M., (2010). A methodology for optimizing feed composition for anaerobic co-digestion of agro-industrial wastes. Bioresour. Technol. 101, 1153–1158.

[6] Bamidele A. Adanikina, Gbolabo A. Ogunwande, and Olusola O. Adesanwo (2017) Evaluation and kinetics of biogas yield from morning glory (Ipomoea aquatica) co-digested with water hyacinth (Eichhornia crassipes). Ecological Engineering 98, 98–104

[7] Chippa, R. C., Krishan , K. V. and P. B. L Chourasia, C., (2014). Study of Biogas Production from Wastes "Cow Dung and Poultry Waste". International Journal of Advances in Engineering & Scientific Research, 1(4), pp. 35-44.

[8] Chuanchai, A., and Ramaraj, R. (2018). Sustainability assessment of biogas production from buffalo grass and dung : biogas purification and bio - fertilizer, 3 Biotech. 8(151): 1–11. https://doi.org/10.1007/s13205-018-1170-x

[9] Chukwuma, E. C., Umeghalu, I. C. E., Orakwe, L. C., Bassey, E. E. and Chukwuma, J. N. (2013) Determination of optimum mixing ratio of cow dung and poultry droppings in biogas production under tropical condition, African Journal of Agricultural Research. 8(18): 1940 – 1948. http://www.academicjournals.org/AJAR

[10] Clarke, W.P., Radnidge, P., Lai, T.E., Jensen, P.D., and Hardin, M.T., (2008). Digestion of waste bananas to generate energy in Australia. Waste Management 28, 527–533.

[11] Fulford, and David. (2011). Biogas Technology: Sussess Project in Asia and Africa, being a Paper Presentation at kingdom BioEnergy, Retrievied on the 5thJune, 2016 at: http://www.kingdombio.com; 65p.

[12] Gallegos, D., Wedwitschka, H., Moeller, L., Weinrich, S., Zehnsdorf, A., Nelles, M., and Stinner, W. (2018). Mixed silage of Elodea and wheat straw as a substrate for energy production in anaerobic digestion plants, Energy, Sustainability and Society 8 (7), 1–8. https://doi.org/10.1186/s13705-018-0148-1

[13] Haryanto, A., Hasanudin, U., Afrian, C., and Zulkarnaen, I. (2018). Biogas production from anaerobic codigestion of cowdung and elephant grass (Pennisetum Purpureum) using batch digester,IOP Conf. Series: Earth and Environmental Science 141: 1 – 10. doi :10.1088/1755-1315/141/1/012011

[14] Hullu, J.D., (2012). Coparing Different Biogas Upgrading Technologies. In Interim Report. Dirkese Milieutechniek, Eindhoven University of technology. Retrived on the 27th May 2016 at http://www.students.chem.tru.org;12p

[15] Ifeanyi, V. O., and Ossai, I. W. (2014). Analysis of Bio-gas Production from Cow Dung by Indigenous Microbial Consortia. British Biotechnology Journal. 4(5): 630-639, https://doi.org/10.9734/BBJ/2014/5834

[16] Ioana, L., and Cioabla, A. (2010). Biogas Production based on Agricultural Residues. Journal of Waste

Transactions on Environment and Development issues,Vol. 6, 2 (2010) 1-13.
[17] Kralik, D., Bukvić, Z., Kukic, S.,. Uranjek, N. and Vukšić, M. (2008). Sudan grass as an energy crop for biogas production, Cereal Research Communications. 36: 579 – 582. https://doi.org/10.1556/CRC.36.2008.Suppl.1
[18] Mallik, M.K., Singh, U.K., and Ahmad, N. (1990). Batch digester studies on biogas production from Cannabis sativa, water hyacinth and crop wastes mixed with dung and poultry litter. Biological Wastes 31, 315–319.
[19] Mbachu, V. M. and Alukwe, U. J. (2019). Biogas Production Using Liquid Extract from Plantain Pseudo Stem. International Journal of Engineering and Industry 2(2): 9 – 14. https://www.zambrut.com. ISSN: 2191-3315.
[20] Mbachu, V. M., Igboanugo, A.C. and Alukwe, U. J. (2019). Development of Enhanced Substrate from Fresh Elephant Grass for Biogas Production. International Journal of Scientific & Technology Research 8(2): 44 – 49. https://www.ijstr.org ISSN 2277-8616
[21] Meshach, I. (2014). Comparative Study of Biogas Production From Cow Dung, Chicken Droppings And Cymbopogon Citratus as Alternative Energy Source in Nigeria. Ahmadu Bello University, Zaria: PGD Education; Retrieved on the 7th of July, 2016 at :http//remade.org.u
[22] Ocwieja, S. (2010). Life Cycle Thinking Assessment Applied to Three Biogas Projects in Central Uganda; 123-130p.
[23] Ofoefule, A.U., Nwankwo, J.I. and Ibeto, C.N (2011). Biogas production from paper waste and its blend with cow dung. Adv. In applied science research. 1(2): 1-8.
[24] Ogunwande, G.A., Muritala, A.O., and Babalola, W.O. (2015). Evaluation of biogas yield from water leaf plant (Talinum triangulare). CIGR J. 17 (1), 110–117.
[25] Ojo, S. J., Oke, S. A., Animasahun, O.K and Adesuyi, B. K (2007). Utilisation of poultry, cow and kitchen wastes for biogas production: A comparative analysis. Iranian Journal of Environmental Health Science and Engineering 4: 223-228.
[26] Patil, J.H., Raj, M.A., Muralidhara, P.L., Desai, S.M., and Raju, G.K.M. (2012). Kinetics of anaerobic digestion of water hyacinth using poultry litter as inoculum. Int. J. Environ. Sci. Dev. 3 (2), 94–98.
[27] Pertiwiningrum, A., Rochijan, R., Fitriyanto, N. A., and Habibi, M. F. (2017). Potential Test on Utilization of Cow's Rumen Fluid to Increase Biogas Production Rate and Methane Concentration in Biogas, Asian Journal of Animal Sciences. 11(2): 82 – 87. https://doi.org/10.3923/ajas.2017.82.87
[28] Rohjy, H.A., Aduba, J.J., Manta, I.H., and Pamdaya, Y. (2013). Development of Anaerobic Digester for the Production of Biogas using Poultry and Cattle Dung: A case study of Federal University of Technology Minna Cattle and Poultry Pen. International Journal of Life Sciences, 2(3), pp. 139-149.
[29] Rozy, Dar, R. A. and Phutela, U. G. (2017) Optimization of Biogas Production From Water Hyacinth (Eichhornia crassipes) Journal of Applied and Natural Science 9 (4): 2062 -2067
[30] Sambo, A. S., Etonihu, A. C., and Mohammed, A. M. (2015) Biogas Production From Co-Digestion Of Selected Agricultural Wastes In Nigeria, International Journal of Research - Granthaalayah.3(11): 7-16 http://www.granthaalayah.com
[31] Samyuktha, S., Latha, K. and Sivanesan, S. (2015) Ratio Optimization for Biogas Production from Agricultural Waste Co-Digested with Sewage Sludge. International Journal of Innovative Research in Engineering & Management (IJIREM), 3(S1): 154 – 156. Available at https://www.researchgate.net/publication/276412507
[32] Sawasdee, V., and Pisutpaisal, N. (2014). ScienceDirect Feasibility of Biogas Production from Napier Grass, Energy Procedia 61; 1229–1233. https://doi.org/10.1016/j.egypro.2014.11.1064
[33] Singhal, V., and Rai, J.P.N., (2003). Biogas production from water hyacinth and channel grass used for phytoremediation of industrial effluents. Bioresource Technology 86, 221–225.
[34] Stephen, C., Ukpabi, C., and Esihe, T. E. (2013) Anaerobic Digester Considerations of Animal Waste, American Journal of Biochemistry 3(4): 93-96. DOI: 10.5923/j.ajb.20130304.02
[35] Summoogum-utchanah, S. L., and Poorneema, D. (2015). An Investigation on the Potential of Biogas Production from Elephant Grass and Guinea Grass, American International Journal of Research in Science, Technology, Engineering & Mathematics. 9(2): 194–197.
[36] Syed, Z. I (2006). A case study to bottle biogas in cylinder as source of power for rural industries development in Pakistan. World Applied Sciences Journal 2: 127-130
[37] Verma, V.K., Singh, Y.P., and Rai, J.P.N., (2007). Biogas production from plant biomass used for phytoremediation of industrial wastes. Bioresource Technology 98, 1664–1669.
[38] Widodo, T., and Hendriadi, A. (2014). Development of biogas for small scale Fram, International Seminar on Biogas technology for Sustainable Development. Beijing. Retrieved on the 2nd of June, 2016 at: http//www.gatetech.org.
[39] Yong, Z., Dong, Y., and Zhang, X. (2015). Anaerobic codigestion of food waste and straw for biogas production. Renew Energ. 2015; 78:527–530.