Advances In Multidisciplinary & Scientific Research
AIMS Research Journal
A Multidisciplinary & Interdisciplinary Journal

Vol. 2, No. 2, June, 2016

Effects of Mixing Ratios of Cow Dung, Cassava Peel and Rice Husk on Thermodynamic Properties and Composition of Biogas in Anaerobic Digester

Olorunmaiye, J.A., Adegun, I.K., Ogunniyi, O.J., Aweda, J.O., Ajiboye, T.K. and Abdulkareem, S.
Department of Mechanical Engineering
University of Ilorin
P.M.B 1515 Ilorin, Nigeria.
Email: adeolorunmaiye@gmail.com
Phone Number: +23480360000053

ABSTRACT

Over the years, one of the major threats to energy usage is the increase in human population, and the low level of production of energy. Biogas, which is a renewable energy source, can be used to complement the existing means of energy generation. The aim of this research is to produce biogas from combination of rice husk with cow dung and cassava peels with cow dung. Five digesters were used for this work having the following contents: digester A contained 16 kg of rice husk and 8 kg of cow dung in 100 kg of water; digester B contained 12 kg of rice husk and 12 kg of cow dung in 85 kg of water; digester C contained 16 kg of cow dung in 75 kg of water; digester D contained 8 kg of cassava peels and 8 kg of cow dung in 120 kg of water; and digester E contained 4 kg of cassava peels and 12 kg of cow dung in 100 kg of water. These were subjected to anaerobic digestion. The temperature and pressure of the gas produced in the digesters after being loaded with the substrates were measured at 12 noon and 6 pm every day for a period of 30 days. The results showed that digester E had the highest temperature of 46 oC, followed by digester D which had temperature of 45 oC. Digester B had the lowest temperature of 30 oC. The highest pressure of 34 mmHg was obtained in digester D, which was observed to have the highest amount of biogas generated, while digesters B and C had the least pressure readings of 6 mmHg. The results also indicated that mixing ratios have significant effects on the temperature, pressure and volume of the biogas generated. The results revealed that the volume of biogas generated from the mixture of plant and animal wastes was more than that of cow dung only.

Keywords: Biogas, digester, temperature, pressure, cassava peel, rice husk, cow dung

---

Aims Research Journal Reference Format:
Olorunmaiye, J.A., Adegun, I.K., Ogunniyi, O.J., Aweda, J.O., Ajiboye, T.K. and Abdulkareem, S. (2016): Effects of Mixing Ratios of Cow Dung, Cassava Peel and Rice Husk on Thermodynamic Properties and Composition of Biogas in Anaerobic Digester. Advances in Multidisciplinary Research Journal. Vol 2, No.2 Pp 169-176

---

1. BACKGROUND TO THE STUDY

Over the years, one of the threats to energy sufficiency is the increase in human population and most of the energy used is non-renewable. The world population was 7.3 billion in 2015 (Population Reference Bureau, 2015) and all these people must be provided with materials and energy resources. Taking cognizance of the fact that fossil fuels exist in limited quantity and also that the products of their combustion contribute to global warming; a revolution towards sustainable energy supply is urgently needed. One of the ways to achieve sustainable energy supply is the increase in the use of biomass to generate renewable energy (Jacobson and Price, 1990). Biogas is generated by the biological breaking down of organic matter such as biomass, sewage, municipal waste, rubbish dumps, septic tanks' content, green waste and energy crops in an anaerobic environment, i.e. absence of oxygen (Aderibigbe, 2015).

To produce biogas, the anaerobic degradation is made to take place in a biogas digester designed for that purpose. The generated biogas is a mixture of methane, carbon-dioxide, and some other gases (Karki et al., 2005). It is used as bio-fuel around the world, and it has a wide range of use such as domestic usage for cooking, industrial usage for electricity generation and as fuel for internal combustion engines (Adegun and Yaru, 2013). It is an attractive energy source, which plays a vital role for stable economic development, rural and agricultural development and environmental protection.

The generation of biogas from livestock manure, sludge, municipal, livestock and organic wastes also serves as a means of generating income for the farmers (Hogan et al., 2010). Cow dung which is seen as an effective feedstock for biogas generation, helps to obtain a high cumulative biogas yield with steady act of performance (Abubakar and Ismail, 2012). Many of the agricultural waste products like maize cob, rice husk, cassava peels etc. become a nuisance, as they are being disposed of inappropriately on the streets or near the sites where these crops are processed. Digestion of these plant and animal wastes can be used to generate biogas (Oparaku et al., 2013)

One of the problems associated with generation of biogas from cassava roots, is its high acidity level, which has an effect on the amount of biogas generated. For optimum amount of biogas to be generated from a waste, it must have a pH value between the range of 6.5 and 8.5. Inoculums and neutralizers can be added to cassava wastes to be used for biogas generation, so as to obtain a neutral pH value (Ofoefule et al., 2010). By using plant and animal waste products to generate biogas, single households and communities can become more or less self sufficient in terms of energy. The biogas generated can be used as a clean cooking fuel without the hazardous smoke experienced when using firewood (Oparaku and Oformata, 2013).

Adegun and Yaru (2013) earlier worked on generation of biogas from cattle dung, considering it a renewable source of energy which can be used in rural areas. The retention period for the biogas generated was 13 days. After the biogas was refined, 70.29 % CH4 composition with 22.62 MJ/m3 calorific values was obtained from it earlier value of 56.20 % CH4 composition and 19.15 MJ/m3 calorific value. Ofoefule and Uzodinma (2009) considered biogas generation from mixture of cassava peels and animal wastes: cassava peels and cow dung; cassava peels and poultry dropping; and cassava peels and swine dung in the ratio of 1:1 and another digester containing cassava peels only. The highest cummulative gas yield was obtained from the blend of cassava peels and swine dung, while the blend of cassava peels and cow dung yield early the flammable gas. All the blend of cassava peels with animal waste produced flammable gas before the 12th day while that of cassava peels only took 59 days.

Cassava peels and pig dung were mixed together in three digesters with different mixing ratio; 50:50, 30:70, 10:90 respectively, and having pig dung only in the 4th digester (Oparaku et al., 2013). All the blend of cassava peels and pig dung generated more gas than that of the pig dung only, with 30:70 having the highest yield and 10:90 having the least. In another work carried out by Ukpai and Nnabuchi (2012), it was shown that blends of cow pea and cow dung yields higher percentage of methane than blend of cassava peels and cow dung, though cow dung alone generates the highest biogas cummulative than its blend with either cow pea or cassava peels. Leke et al. (2013) worked on blends of cow rumen liquor, poultry droppings, and goat faeces with maize cobs. For three digesters, 20 g of each animal wastes were mixed with 100 g of degraded maize cobs in a seperate digester, the forth one was a blend of 10 g of cow rumen liquor, 10 g of poultry droppings and 100 g of maize cobs, and the fifth one was 100 g of maize cobs alone. The blend of cow rumen liquor, poultry droppings with maize cobs generates the highest amount of biogas followed by the blend of cow rumen liquor with maize cobs, while the maize cobs alone produced the least.

From the work of Vivekanandan and Kamaraj (2011a) on biogas production from mixture of rice chaff (karukka) and cow dung; it was obseved that raw(unboiled) rice chaff contained high amount of lignin with low cellulose value which cause it to have low potency of biogas generation, unlike when it is boiled. Using of innoculum as seeding agent initially in the biogas digester can also increase the amount of biogas generated (Ezekoye et al., 2014).

2. OBJECTIVE

The purpose of this work is to determine which blend of cassava peels, rice husk and cow dung will generate more biogas and the thermodynamic properties and chemical composition of the biogas produced.

3. METHODOLOGY

3.1 Materials Consideration

The details of design calculations for the digesters are presented else where (Ogunniyi, 2015). For the construction of the digester, plastic materials were used for the drums and pipe, due to its resistance to corrosion (Olorunmaiye et.al, 2016). The pipes were fixed to the digester to serve as inlet and outlet duct for loading of the substrate and discharge of the slurry respectively. A pipe equipped with a valve was connected to the upper part of the inverted drum through which the gas is collected.

Thermocouples (Type K) were used with a multi-meter (MASTECH - MY64) in taking the temperature readings inside the digesters, while Sphygmomanometers (CE 0483) were used in taking the pressure readings.

The systems were made to be air tight, so as to have an anaerobic condition, which is required for digestion processes. Empty cylinders were used in storing the biogas after they were collected from the digesters using gas spooter.

The diagram of a digester is shown in Figure 1. Figure 2 is a photograph of the experimental set up which was placed under a shed.

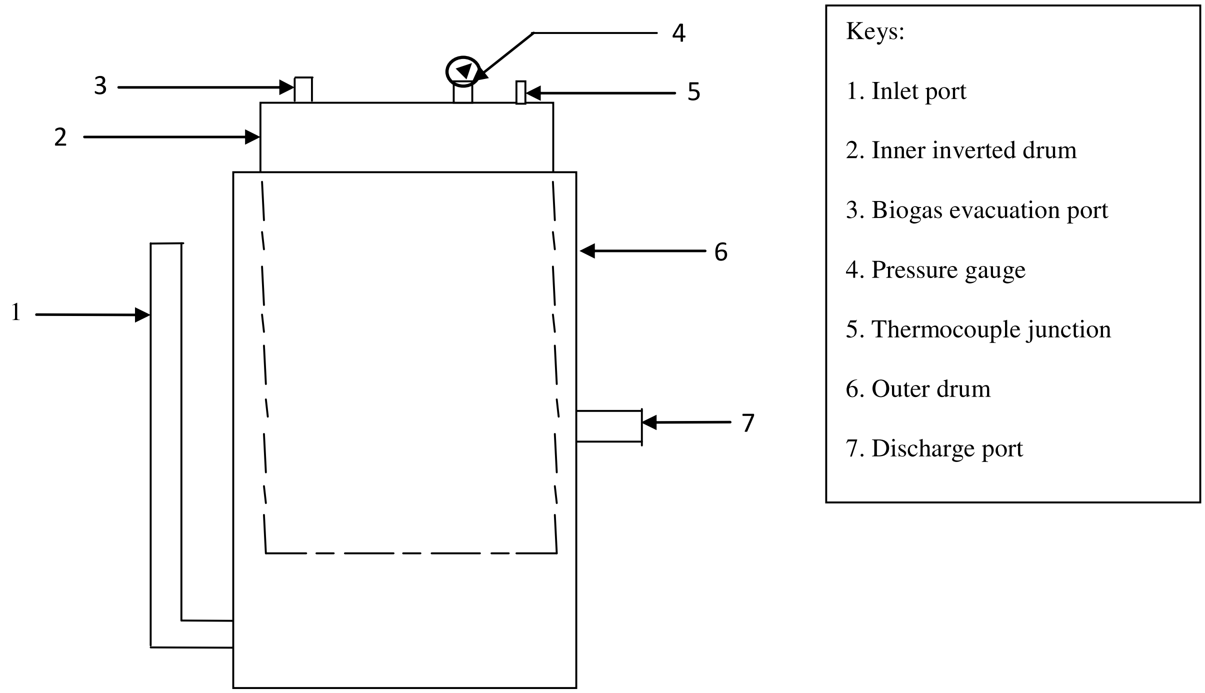

Figure 1: Assembly of the digester

Figure 2: The five digesters under a shed.

3.2 Experimental Procedure

Cassava peel and rice husk are the agricultural wastes that were collected with cow dung from Abakaliki in Ebonyi state of Nigeria. Five digesters were used for this research work; two for different mixing ratio of rice husk with cow dung, another two for different mixing ratio of cassava peel and cow dung, and the last one for cow dung only. The digesters were labeled A to E for easy identification and were filled with the constituents, which was mixed with water. The constituents of the five digesters are in Table 1:

Table 1: The Constituents of the five digesters

	Rice Husk (kg)	Cassava Peel (kg)	Cow Dung (kg)	Water (kg)
Digester A	16	-	8	100
Digester B	12	-	12	85
Digester C	-	-	16	75
Digester D	-	8	8	120
Digester E	-	4	12	100

As shown in Table 1 above, digesters A and B contained mixtures of rice husk and cow dung with different mixing ratios which were thoroughly mixed before water was added, so as to achieve a uniform mixture within the digesters. Also, digester D and E contained mixtures of cassava peel and cow dung which were thoroughly mixed. While digester C contained cow dung only, that was mixed with water.

The temperature and pressure readings of the biogas inside the digesters were taken at 12 noon and 6 pm every day during the period of the experiment. Type k thermocouples connected to multi-meter which has cold junction compensation was used in taking the temperature measurements, while Sphygmomanometers (CE 0483) was used for measuring the pressure.

4. RESULTS AND DISCUSSION

The readings taken during the period of the experiment were recorded and presented in figures 3 to 6. Figure 3 shows the graph for the temperature readings within the five digesters at 12 noon during the period of the experiment. Digester E had the highest temperature reading of 46 oC on the 7th day with digester D having temperature of 45 oC on the same day. Digester B had the lowest temperature readings of about 30oC during the experiment for a period of about 9 days during the experiment. On the average, digester D had the highest temperature reading value while digester B had the lowest temperature during the period of the experiment.

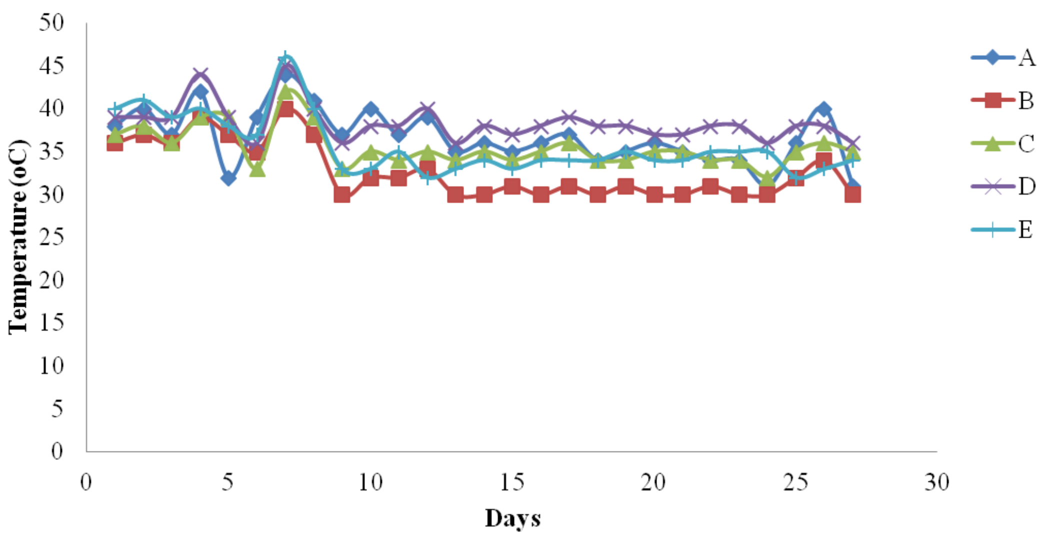

Figure 3: Graph of Temperature Reading against Period (Days) at 12 noon

Figure 4 shows the daily pressure readings taken during the experiment at 12 noon. Digester D had the highest pressure of about 34 mmHg on the 13th day of the experiment. Afterwards, the pressure drops a little, and behaved in a sinusoidal way during the remaining days of the experiment. Digesters B and C had the lowest pressure during the experiment, with the highest pressure value of 6 mmHg, but most of the pressure readings were about 2 mmHg.
Digester A experienced a drastic rise in pressure after the 2nd day of the experiment while that of digesters D and E were after the 3rd day. There was a continuous rise of the pressure inside digester D until the 13th day when the pressure drops a little and behaved in a sinusoidal way during the remaining days of the experiment. The pressure in digesters A and E dropped after the 3rd day and fluctuated throughout the period of the experiment.

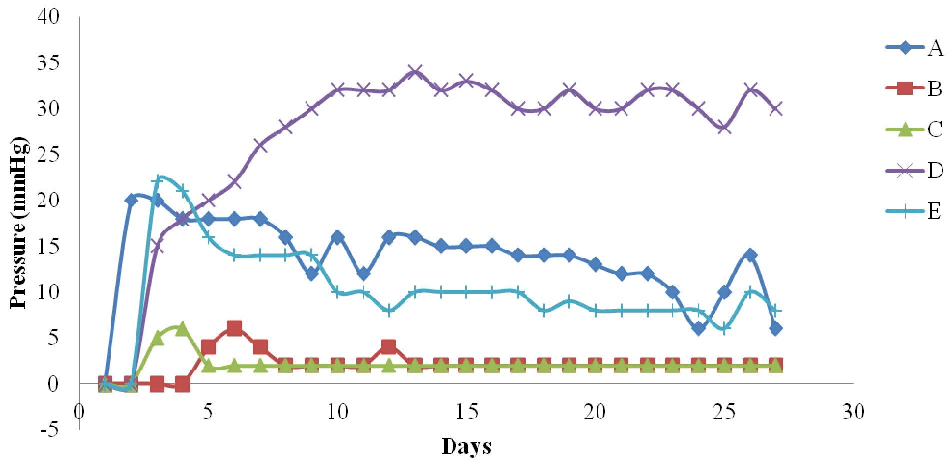

Figure 4: Graph of Pressure readings against Period (Days) at 12 noon

Figures 5 and 6, show the temperature and pressure readings inside the digesters at 6 pm during the experiment. The temperature and pressure readings here, also behaves like that of 12 noon which were shown in figures 3 and 4, though the temperature and pressure values were not up to that of at 12 noon. On the average also, digester D had the highest temperature and the highest pressure, while digesters B and C had the lowest pressure of 2 mmHg during the period. Digesters A and C experienced the lowest temperature values during the digestion period.

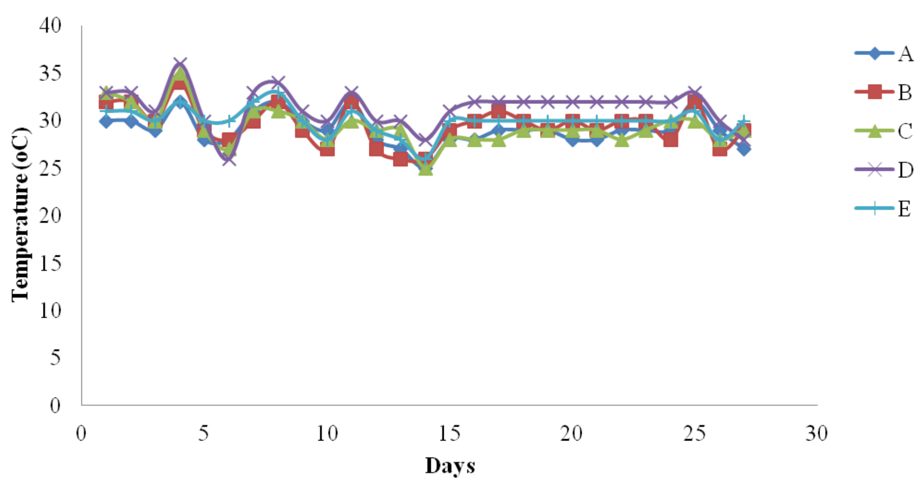

Figure 5: Graph of Temperature reading against Period (Days) at 6 pm

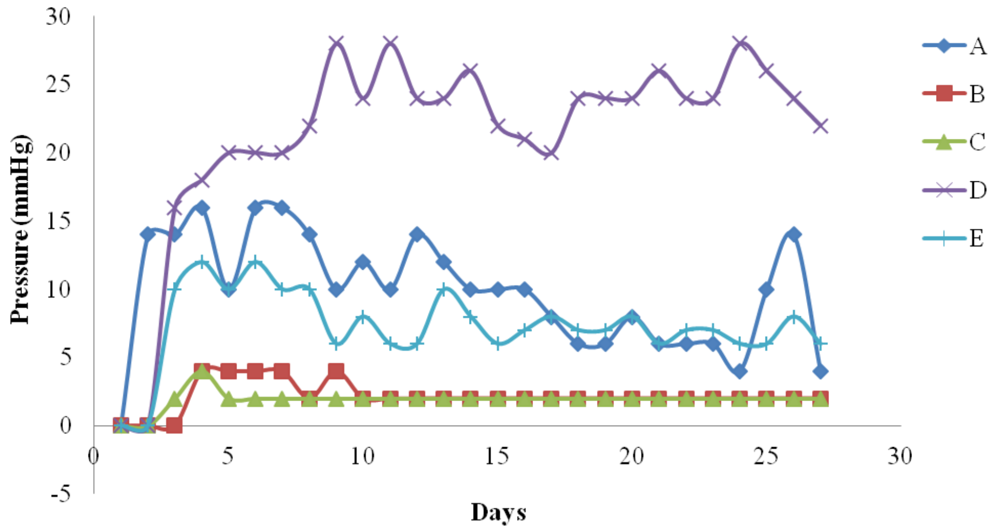

Figure 6: Graph of Pressure readings against Period (Days) at 6 pm

From the results, it is evident that the bacteria are more active at 12 noon than that of 6 pm; more energy is generated by bacteria (exothermic reaction) which results in high temperature at 12 noon. From the temperature and pressure readings, digester D will have the highest amount of biogas generated, followed by that of digester A. One of the major effects on the results was the volume of the substrate used for the experiment; the amount of biogas generated from the substrate was low. The mixing ratio of the substrate also had effect on the biogas yielded by each of the digesters. Digester D contains 50% of cassava peels and 50% of cow dung by weight, which had higher volume than the other substrate; which allows it to generate more biogas than the others. Digester E had 33% of cassava peel and 67% of cow dung; the volume of the substrate was low when compared to that of digester D. Oparaku et al. (2013) who worked on blend of cassava peel and pig dung, also reported that the blend of cassava peels with animal waste generate more biogas than using only the plant or animal waste. Combination of cassava peels and animals wastes aids the relatively low flammable biogas generation and the slow onset of gas flammability (Ofoefule and Uzodinma, 2009).

Digester A contains 66.7% of rice husk with 33.3% of cow dung by weights, which also yielded more than digester B which contains 50% of rice husk and 50% of cow dung. From these results, it is evident that having larger percentage weight of the plant waste to that animal waste will generate more biogas. This is in agreement with the result of Vivekanandan and Kamaraj (2011b) who discovered that a mixture of cow dung and rice chaff in ratio 1:3 will generate more biogas, though he pretreated it with sodium hydroxide (NaOH). It was observed that rice husk generates more biogas than cow dung, but the mixture of the two will yield more biogas. Small amount of biogas was generated by digesters B and C compared to those of digesters A, D and E. The factors observed to be responsible for these were the mixing ratio for the mixture and the volume of the substrate compared to the total volume of the digester. The biogas were tested for combustion, biogas from digesters A, D and E burnt while those of digesters B and C did not.

The biogas generated were analysed and the percentage composition of the compounds obtained are presented in Table 2.

Table 2: Result of the Percentage Composition of each Samples.

% Composition / Digester	CH_4	CO_2	H_2S	N_2	H_2	O_2	Others
A	58.13	23.37	0.13	6.68	0.06	0.22	11.41
B	56.80	21.44	0.10	8.78	0.10	0.39	12.39
C	52.80	26.05	0.28	5.90	0.08	0.46	14.43
D	51.98	24.88	0.24	7.92	0.06	0.45	14.47
E	50.82	22.36	0.22	8.88	0.08	0.50	17.14

The percentage of methane composition in the production of biogas determines it combustibility. From the result of the analysis, all the biogas generated had more than 50 % composition of methane; the blends of rice husk and cow dung had the highest percentage of methane, followed by that of cow dung only, while the blends of cassava peels and cow dung had the least. The biogas generated from cow dung only had the highest percentage of carbondioxide and hydrogen sulphide than its blends with plant wastes.

5. CONCLUDING REMARKS

It can be concluded that more biogas is produced from mixture of plant and animal waste than from plant waste or animal waste alone. To maximize biogas produced, the plant waste should be of higher percentage than animal waste. Therefore a digester with such substrate should be designed to withstand high pressure to prevent rupture of the digester and leakage of combustion gas into the ambient air which may lead to explosion.

ACKNOWLEDGEMENT
The authors gratefully acknowledge the sponsorship of this project through year 2014 TETFUND institution-based research grant.

REFERENCES

1. Abubakar, B.S.U. and N. Ismail (2012). “Anaerobic digestion of cow dung for biogas production”, ARPN Journal of Engineering and Applied Sciences, Vol. 7, No. 2, pp. 169 - 172.
2. Adegun, I.K. and S.S.Yaru, (2013). “Cattle dung biogas as a renewable energy source for rural laboratories”, Journal of Sustainable Technology, Vol. 4, No. 1, pp. 1 - 8.
3. Aderibigbe, A.B. (2015). “Design and construction of 250 liters plastic bio-digester and evaluation of biogas production using 4 co-substrates”, The Institute of Integrative Omics and Applied Biotechnology Journal, Vol. 6, No. 2, pp. 1 - 6.
4. Ezekoye, V. A., Onah, D. U., Offor, P. O. and B.A. Ezekoye (2014). “Characterization of Biogas Produced from Rice Husks and Algae using a Metal Fixed-Dome Biodigester”, Global Journal of Science Frontier Research: G Bio-Tech & Genetics, Vol. 14, Iss. 1, Ver. 1, pp. 1 - 8.
5. Hogan, M., Otterstedt, J., Morin, R. and J. Wilde (2010). "Biomass for heat and power - Opportunity and economics”, available at: http://www.europeanclimate.org/documents/Biomass_report_-_Final.pdf (accessed on 26/8/2015).
6. Jacobson, H.K. and M.F. Price (1990). “A Framework for Research on the Human Dimensions of Global Environmental Change”, International Social Science Council.
7. Kaneda, T. and K. Bietsch (2015). “2015 World Population Data Sheet”, Population Data Bureau, available at: www.prb.org/pdf15/2015-world-population-data-sheet_eng.pdf (accessed on 29/02/2016).
8. Karki, A.B., Shrestha, J.N. and S. Bajgain (2005). “Biogas: As Renewable Source of Energy in Nepal” Theory and Development; BSP-Nepal Kathmandu.
9. Leke, L., Ogbanje, A.A., Terfa, D.H. and T. Ikyaagba (2013). “Production of biogas from maize cobs”, International Journal of Energy and Environment, Vol. 4, No. 1, pp.153-160.
10. Ofoefule, A.U., Eme, E.L., Uzodinma, E.O. and C.N. Ibeto (2010) “Comparative study of the effect of chemical treatments on cassava (Manihot utilissima) peels for biogas production”, Scientific Research and Essays, Vol. 5, No. 24, pp. 3808-3813.
11. Ofoefule, A.U. and E.O.Uzodinma. (2009). “Biogas production from blends of cassava (Manihot utilissima) peels with some animal wastes”, International Journal of Physical Sciences, Vol. 4, No. 7, pp. 398-402.
12. Ogunniyi, O.J. (2015). “Biogas generation from cow dung and mixture of cow dung with some plant wastes”, M. Eng. Thesis Report, Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria.
13. Olorunmaiye, J.A., Adegun, I.K., Ogunniyi, O.J., Aweda, J.O., Ajiboye, T.K. and S. Abdulkareem (2016). “Effects of Mixing Ratios of Cow Dung, Cassava Peel and Rice Husk on Thermodynamic Properties of Biogas in Anaerobic Digester”, Proceedings of the iSTEAMS Multidisciplinary Cross-Border Conference, Ser. 9, Vol. 1, pp. 526 - 534.
14. Oparaku, N.F. and A.C. Oformata. (2013), “Biodegradation of agricultural waste and pig dung in anaerobic digester”, Journal of Physical Sciences, Vol. 1, No. 4, pp. 62 - 68.
15. Oparaku, N.F., Ofomatah, A.C. and E.C. Okoroigwe. (2013). “Biodigestion of cassava peels blended with pig dung for methane generation”, African Journal of Pig Farming, Vol. 1, No. 2, pp. 23-27.
16. Rouf, M.A. and N. Haque. (2008). “Role of Renewable Energy (Biogas and Improved Cook Stoves) for Creation of Green Jobs in Bangladesh”, Workshop on Green Jobs Initiative in Bangladesh, Bangladesh, Dhaka.
17. The Engineering ToolBox; Thermoplastics - Physical Properties; available at: http://www.engineeringtoolbox.com/physical-properties-thermoplastics-d_808.html (accessed on 28/08/15).
18. Ukpai, P. A. and M.N. Nnabuchi (2012). “Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digester”, Advances in Applied Science Research, Vol. 3, No. 3, pp. 1864 - 1869.
19. Vivekanandan, S. and G. Kamaraj (2011a). “The study of biogas production from rice chaff (karukka) as co-substrate with cow dung”, Indian Journal of Science and Technology, Vol. 4, No. 6, pp. 657 - 659.
20. Vivekanandan, S. and G. Kamaraj (2011b). “Investigation on cow dung as co- substrate with pretreated sodium hydroxide on rice chaff for efficient biogas production”, International Journal of Science and Advanced Technology, Vol. 1, No. 4, pp. 76 - 80.