

*Full Length Research paper*

# The study of cow dung as co-substrate with rice husk in biogas production

Elijah T. Iyagba<sup>1\*</sup>, Ibifuro A. Mangibo<sup>2</sup> and Yahaya Sayyadi Mohammad<sup>1</sup>

<sup>1</sup>Department of Chemical Engineering, University of Port Harcourt, Choba, P. M. B. 5323, Port Harcourt, Rivers State, Nigeria.

<sup>2</sup>Department of Petroleum and Gas Engineering, University of Port Harcourt, Choba, P. M. B. 5323, Port Harcourt, Rivers State, Nigeria.

Accepted 28 July, 2009

**The co-digestion of cow dung with rice husk for biogas production at laboratory scale was the subject of this investigation. The study was carried out at room temperature that is, 26 - 29°C for a period of 52 days with a total solid concentration of 8% in each sample (fermentation slurry). The biogas produced was collected by water displacement method which was subsequently measured. Sample A (50 wt % cow dung, 50 wt % rice husk) showed a cumulative biogas production of 161.5 ml at the end of the 38<sup>th</sup> day of the experiment after which there was no further production. The production from sample B (25 wt % cow dung, 75 wt % rice husk) was not significant, while there was no production from sample C (0 wt % cow dung, 100 wt % rice husk).**

**Key words:** Biogas, cow dung, rice husk, co-digestion.

## INTRODUCTION

Rice husk is an agricultural waste which remains after the processing of the crop. This waste can be transformed either by chemical and/or biological means (Vigil et al., 1993). The biological process may be accomplished either aerobically or anaerobically, depending on the availability of oxygen. The composition of rice husk varies widely as follows: Crude protein, 1.7 - 7.26%; Crude fat, 0.38%; Nitrogen free extract, 24.70 - 38.79%; Crude fiber, 31.71 - 49.92%; Ash, 13.16 - 29.04%; Pentasans, 16.94 - 21.95%; Cellulose 34.34 - 43.80%; Lignin 21.40 - 46.97% (Pillaier, 1988). This shows that the lignin content in rice husk is relatively very high. Alexander (1977) reported that the outstanding micro-biological characteristics of lignin are its resistance to enzymatic degradation.

Biogas is a term used to represent a mixture of different gases produced as a result of the action of anaerobic microorganisms on domestic and agricultural waste (McInerney and Bryant, 1981; Ezeonu et al., 2005). It usually contains 50% and above methane and other gases in relatively low proportions namely, CO<sub>2</sub>, H<sub>2</sub>, N<sub>2</sub> and O<sub>2</sub>

(Milono et al., 1981; Kalia et al., 2000). The mixture of the gases is combustible if the methane content is more than 50% (Agunwamba, 2001). Biogas production involves three steps:

- i. Hydrolysis:** Which converts organic polymers into monomers (with the help of hydrolytic bacteria).
- ii. Acid formation:** Which involves conversion of monomers into simple compounds such as acetic acid, propionic acid, CO<sub>2</sub>, NH<sub>3</sub> and H<sub>2</sub>, using a group of acid forming bacteria (acetogenic bacteria).
- iii. Methane formation:** Involving conversion of simple compounds into methane CH<sub>4</sub> and CO<sub>2</sub>, utilizing anaerobic methanogenic bacteria.

Co-digestion is the simultaneous digestion of more than one type of waste in the same unit (Agunwamba, 2001). Advantages include better digestibility, enhanced biogas production/methane yield arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing (Agunwamba, 2001; Mshandete and Parawira, 2009; Parawira et al., 2004). Studies have shown that co-digestion of several substrates, for example, banana and plantain peels, spent grains and rice husk, pig waste and cassava peels, sewage and

\*Corresponding author. E-mail: [et.iyagba@uniport.edu.ng](mailto:et.iyagba@uniport.edu.ng). Tel.: +234 803 405 2225.

brewery sludge, among many others, have resulted in improved methane yield by as much as 60% compared to that obtained from single substrates (Ezekoye and Okeke, 2006; Ilori et al., 2007; Adeyanju, 2008; Babel et al., 2009). Results of co-digestion of food waste and dairy manure in a two-phase digestion system conducted at laboratory scale showed that the gas production rate (GPR) of co-digestion was enhanced by 0.8 - 5.5 times as compared to the digestion with dairy manure alone (El-Mashad and Zhang, 2007). A wide variety of substrates, animal and plant wastes, as well as industrial wastes such as carbonated soft drink sludge and brewery wastes have been used for biogas production (Mackie and Bryant, 1995; Zhang and Zhang, 1999; Kivaisi, 2002; Uzodima et al., 2007; Nagamani, 2007; Uzodima et al., 2008). In these studies, the rate of biogas production was found to depend on several factors such as pH, temperature, C:N ratio, retention time, etc.

The need for more research into biogas production as a renewable energy source alongside the added benefit of solving major environmental problems posed by the wastes used as substrates is well established. Given the large scale production of rice in Northern parts of Nigeria and the level of cattle rearing in the country, large quantities of cow dung and rice husk are produced annually. This work was carried out to explore the potential of biogas production from co-digestion of rice husk and cow dung.

## METHODOLOGY

### Design method

The study was conducted by varying the proportion of biomass to be co-digested while the amount of total solid and detention time were kept constant. Also, the ratio of amount of total solid to water in each of the fermentation digester was the same.

### Sample collection

Cow dung was obtained from the abattoir situated in Choba community of Rivers state, Nigeria. Approximately 1.5kg of cow dung was collected for the purpose of this research. The cow dung collected was sun dried and thereafter crushed mechanically using a mortar and pestle to ensure homogeneity.

Rice husk was obtained from a rice producing community in the northern part of the country, which is Doko town in Niger State. Also, approximately 1.5 kg of rice husk was collected for the purpose of this research. The rice husk obtained was crushed to a coarse form using a mortar and pestle as well.

### Materials/instruments

The following materials/instruments were used for the purpose of this research: Buckner flask (500 and 1000 ml), conical flask (250 ml), measuring cylinder (50 ml), a top loading weighing balance (Model BH 600) with a capacity of 600 g and resolution of 0.01 g, digital pH meter (HANNA Model PH-211), a mercury-in-glass thermometer (range -10°C – 100°C, accuracy  $\pm 0.1$ , Sodium Chloride (NaCl), tap water, mortar and pestle, corks and connecting tubes.

### Apparatus set-up

All apparatus were properly washed with soap solution and allowed to dry by standing over night in the laboratory. A set of 3 Buckner flasks (500 ml) was used as digesters for this research, that is, one digester for each sample. Another set of 3 Buckner flasks (1000 ml) was used. Each contained a solution and was connected to a particular digester by means of a connecting tube and also, on the other side, connected to a conical flask by means of a connecting tube.

Thus, the biogas produced in the digester by the fermentation slurry (sample) passed through the connecting tube to the Buckner flask containing solution. The pressure of the biogas produced caused a displacement of the solution through a connecting tube on the other side of the conical flask.

The weighing balance was used to determine the mass of cow dung and rice husk that made up the total solid for particular fermentation slurry. The digester was operated at ambient temperatures. A thermometer was used to determine the daily temperature. The average temperature was calculated and assumed to be the operating temperature. A digital pH meter was used to determine the pH of the fermentation slurry (sample) on the first day of the experiment.

### Parameters of biogas production and their selected operating conditions

The research was carried out under room temperature that varied between 26 and 29°C, which represents mesophilic condition. pH values for samples A, B and C were 7.29, 7.13 and 6.69, respectively, which were all within the pH range for biogas production. Also a retention time of 52 days was selected for this work.

### Water content

The water content for each sample was determined using the recommendation for better biogas production as reported by Iuen et al. (2007), that is, a total solid (TS) of 8% in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solid. Hence the proportion of total solid to water was the same in all the fermentation slurry samples.

### Total solid content

For the purpose of this research, there were three x: y proportions aimed at investigating the efficiency of rice husk in biogas production. The three proportions were as follows: Sample A; 50:50, B; 75:25, C; 0:100, cow dung: rice husk on a weight percent basis (Table 1).

### Fermentation slurry

Preparation of fermentation slurry was by the addition and vigorous mixing of total solid with an equivalent amount of water needed for maximum yield (Table 2). This mixture was the sample contained in the digester.

### Acidified brine solution and biogas measurements

In order to prevent the dissolution of biogas in the water, an acidified brine solution was prepared by adding NaCl to water until a supersaturated solution was formed. Little drops of sulphuric acid were added to acidify the brine solution. This formed the solution contained in the second Buckner flask (1000 ml). As biogas

**Table 1.** Proportion of substrates in each sample.

Samples (Proportion)	% of x	% of y
A	50	50
B	75	25
C	0	100

x represents the cow dung.; y represents the rice husk.

**Table 2.** Composition of materials in each sample.

Sample	Mass of z (g)	Mass of x (g)	Mass of y (g)	w (g)
A	15	7.5	7.5	172.5
B	15	3.75	11.25	172.5
C	15	0	15	172.5

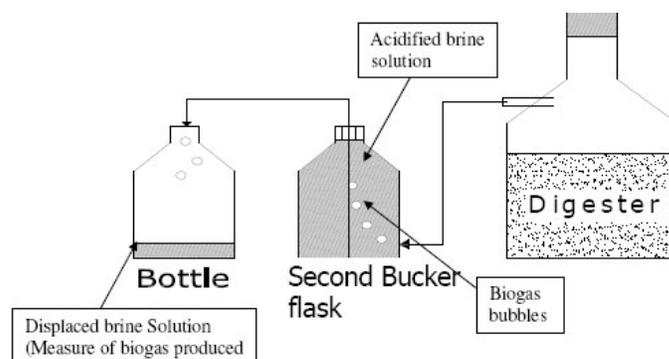
x represents the cow dung; y represents the rice husk.; z represents the sum of the rice husk and cow dung, that is, total solids; w represents the amount of water needed for any given mass of z.

production commenced in the fermentation chamber, it was delivered to the second chamber which contained the acidified brine solution. Since the biogas is insoluble in the solution, a pressure build-up provided the driving force for displacement of the solution. The displaced solution was measured to represent the amount of biogas produced (Itodo et al., 1992). Figure 1 is a schematic diagram of the experimental set-up

## RESULTS AND DISCUSSION

### Biogas production

The biogas production with time from samples A, B and C are shown in Table 3. Sample A (50 wt % cow dung, 50 wt % rice husk) was observed to produce the highest quantity of biogas. As shown in Figure 2, the initial anaerobic digestion process that produced 27 and 30 ml of biogas on the 3<sup>rd</sup> and 5<sup>th</sup> days, respectively is followed by 31 days of inactivity before a sudden burst of production of 78 ml. This inactivity is probably due to the methanogens undergoing a methamorphic growth process by consuming methane precursors produced from the initial activity as suggested by Lalitha et al. (1994), Bal and Dhaghat (2001). It is generally agreed that at the initial stages of the overall process of biogas production, acid forming bacteria produce Volatile Fatty Acids (VFA) resulting in declining pH and diminishing growth of methanogenic bacteria and methagogenesis (Vicenta et al., 1984; Cuzin et al., 1992). That is, a low pH value inactivated microorganisms responsible for biogas production. The variation of bacterial counts of the fermentative bacteria and the methanogenic bacteria with pH may also explain the drop in production after the 36<sup>th</sup> day, followed by some production on the 38<sup>th</sup> day of 26.5 ml, after which no appreciable production of biogas occurred until the 52<sup>nd</sup> day. A recent study of biogas

**Figure 1.** Schematic diagram of experimental set-up.

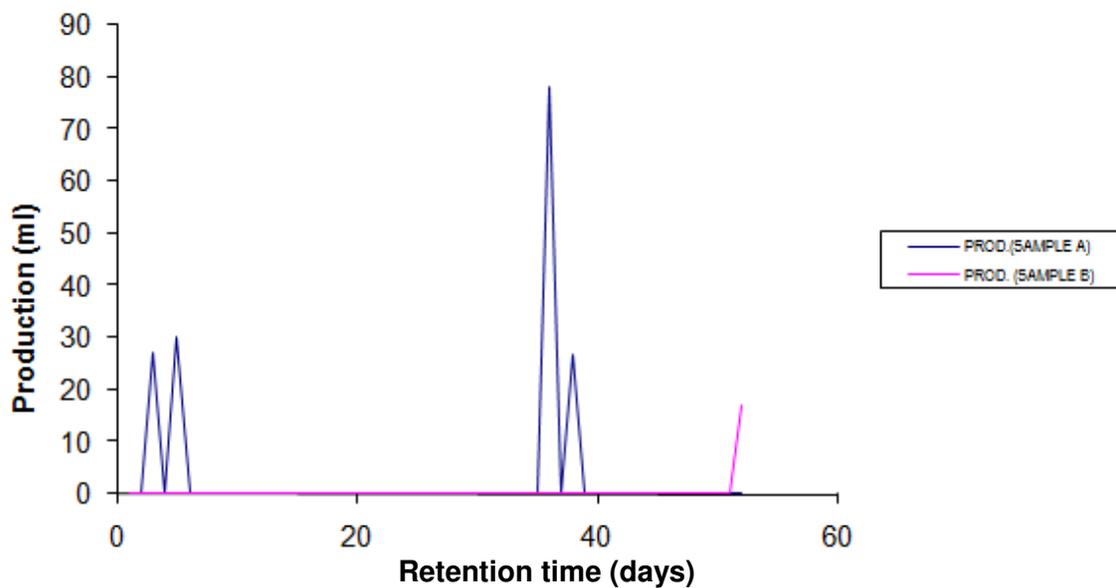
production from co-digestion of a 60:40 wt % of cattle dung and sinews gave a maximum biogas production of 3.3 L/day at 33 days after a 20-day period of inactivity (Pualchamy et al., 2008). Saev et al. (2009) also reported a period of 20 days of minimal biogas production in their study of co-digestion of wasted tomatoes and cattle dung. The longer period of inactivity in our study may be as a result of the complexity of biodegradation involving a high content lignin material present in rice husk. Consequently, the cumulative biogas production increased in a step-wise fashion (Figure 3) due to the periods of inactivity between the periods of production. The cumulative gas production of sample A (50% cow dung, 50% rice husk) on the 38<sup>th</sup> day was 161.5 ml (Table 3). Gadre et al. (1990), from their investigation of the optimum time for the production of biogas from cow dung reported that 15 days retention time was the best for maximum production of biogas from cow dung. They attributed the poor performance at low retention times to accumulation of volatile fatty acids and opined that at retention times greater than 15 days, the digester components were under-utilized. Again, the presence of rice husk for the purpose of co-digestion may be responsible for the variation in optimum retention times observed.

At the end of the experiment the biogas yield of sample A (50% cow dung, 50% rice husk) per total solid was observed to be 10.78 ml/g total solid (Table 4). Hansen (2007) reported that using 100% cow dung under the same condition of temperature and retention time (of 38 days), the cumulative biogas yield would be 26 ml/g total solid. This wide difference may suggest that there was no contribution of biogas production from rice husk.

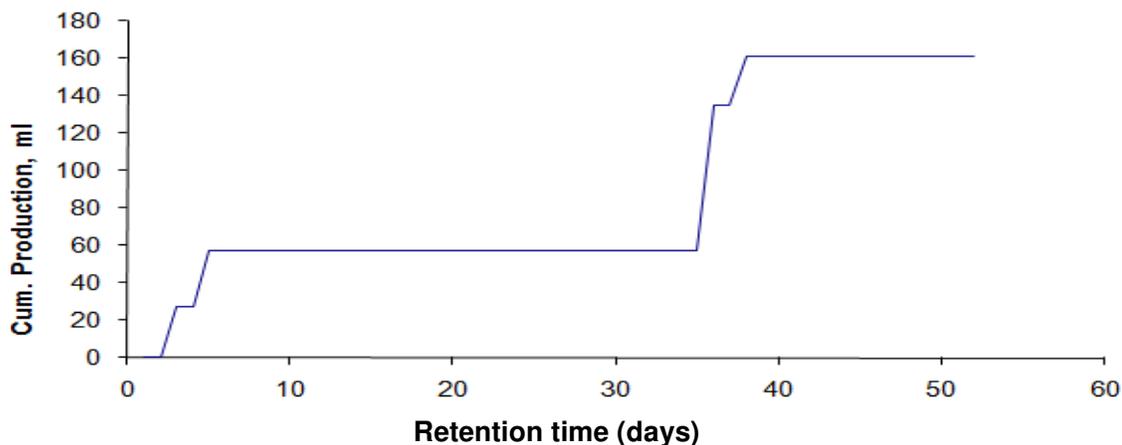
Considering only the 50% cow dung of sample A which makes a total solid of 7.5 g and assuming that the total biogas production of 161.5 ml is from the cow dung only, then the cumulative biogas yield per total solid (7.5 g of cow dung) would be 22 ml/g total solid. Therefore, the 22 ml/g total solid obtained by considering only the 50% cow dung of sample A which makes a total solid of 7.5 g compares favorably with the 26 ml/g total solid obtained under the same condition of temperature and retention

**Table 3.** Daily and cumulative biogas production with time.

Day	Sample A (ml)		Sample B (ml)		Sample C (ml)
	Daily production	Cumulative production	Daily production	Cumulative production	
1	-	-	-	-	-
2	-	-	-	-	-
3	27	27	-	-	-
4	-	27	-	-	-
5	30	57	-	-	-
6 - 35	-	57	-	-	-
36	78	135	-	-	-
37	-	135	-	-	-
38	26.5	161.5	-	-	-
39 - 51	-	161.5	-	-	-
52	-	161.5	17	17	-



**Figure 2.** Biogas production with time at different mixing ratios.



**Figure 3.** Cumulative biogas production with time for sample A (50 wt % cow dung: 50 wt % rice husk).

**Table 4.** Cumulative biogas yield of sample A per total and volatile solid.

Day	Gas yield (ml/gTS)	Gas yield (ml/gVS)
1	-	-
3	1.8	2.26
5	3.8	4.76
36	9.0	11.28
38	10.78	13.49
52	10.78	13.49

TS: total solid; VS: volatile solid.

From Table 3, sample B (25% cow dung, 75% rice husk) was observed to produce a total amount of 17 ml of biogas though this production was observed on the 52<sup>nd</sup> day of the experiment. The volume of biogas produced by this sample was very small. Sample C (100% rice husk) did not produce biogas throughout the period of the experiment. It is well known that the composition of biogas as well as biogas yields depend on the substrates owing to differences in material characterization in each feed material (Calzada et al., 1984; Cuzin et al., 1992; Kalia et al., 2000; Zhang and Zhang, 1999; Momoh, 2004). Given the high cellulose and lignin content of rice husk, it is not surprising that it is resistant to enzymatic degradation and hence, biogas production (Pillaiyer, 1988). Studies on possible uses of rice husk have indicated its potential use in electricity generation, followed by husk-ash fertilizer application (Ueda et al., 2007; Rozainee et al., 2008). It would appear, however, that rice husk does not have any potential for biogas production, at least at room temperature.

## Conclusion

The outcome of this research suggests that rice husk does not have the potential for biogas production at the temperature range of 26 - 29°C and that the co-digestion of rice husk with cow dung at this temperature does not improve the digestibility of rice husk for biogas production.

Although, rice husk does not show any significant contribution in biogas production in the co-digestion of rice husk and cow dung, the residue which contains rice husk can be a source of fertilizer.

## REFERENCES

- Adeyanju AA (2008). Effect of seeding of wood-ash on biogas production using pig waste and cassava peels. *J. Eng. Appl. Sci.* 3: 242-245.
- Agunwamba JC (2001) "Waste Engineering and Management Tool" Immaculate Publication Limited, Enugu.
- Alexander M (1977) *Introduction to Microbiology*, Wiley Eastern Limited, New Delhi, India
- Babel S, Sae-Tang J, Pecharaply A (2009). Anaerobic co-digestion of sewage and brewery sludge for biogas production and land application. *Int. J. Environ. Sci. Tech.* 6: 131-140.
- Bal AS, Dhagat NN (2001). Upflow anaerobic sludge blanket reactor - a review. *Indian J. Environ. Health* 43: 1-82
- Calzada JF, De Porres E, Yurrita A, De Arriola MC, De Micheo F, Rolz C, Menchu JF (1984). Biogas production from coffee pulp juice: one and two-phase systems. *Agricultural Wastes* 9: 217-230.
- Cuzin N, Farinet JL, Segretain C, Labat M (1992). Methanogenic fermentation of cassava peel using a pilot plug flow digester. *Bioresource Technol.* 41: 259-264.
- El-Mashad HM, Zhang R (2007). Co-digestion of food waste and dairy manure for biogas production. *Trans. ASABE* 50: 1815-1822.
- Ezeonu SO, Dioha IJ, Eboatu AN (2005). 'Daily Biogas Production from different wastes and identification of methanogenic bacteria involved. *Nig. J. Solar Energy* 15: 80-85.
- Ezekoye VA, Okeke CE (2006). Design, construction and performance evaluation of plastic bio-digester and the storage of biogas. *The Pacific J. Sci. Technol.* 7: 176-184
- Gadre RV, Ranade DR, Godbole SH (1990). *Indian J. Environ. Health* 32: 45-49
- Hansen C (2007). *Biogas Production and Utilization Explained*. Webpage: <http://www.energyfarms.net/>.
- Ilori MO, Adebuseye A, Lawal AK, Awotiwon OA (2007). Production of biogas from banana and plantain peels. *Adv. Environ. Biol.* 1: 33-38.
- Itodo IN, Lucas EB, Kucha EI (1992). The Effect of Media Materials and its Quality on Biogas Yield. *Nig. J. Renewable Energy* 3 (1, 2)
- Ituene EE, John NM, Bassey BE (2007). Biogas production from organic waste in Akwa Ibom State of Nigeria. *Appropriate Technologies for Environmental Protection in the Developing World. Selected Papers from ERTEP 2007*, July 17-19, Ghana.
- Kalia VC, Sonakya V, Raizada N (2000). Anaerobic digestion of banana stems waste. *Bioresour. Technol.* 73: 191-193.
- Kivaisi AK (2002). Pretreatment of Robusta coffee hulls and co-digestion with cow dung for enhanced anaerobic digestion. *Tanz. J. Sci.* 28:1-10.
- Lalitha K, Swaminathan KR, Bai RP (1994). Kinetics of biomethanation of solid tannery waste and the concept of interactive metabolic control. *Appl. Biochem. Biotechnol.* 47: 73-87.
- Mackie RI, Bryant MP (1995). Anaerobic digestion of cattle waste at mesophilic and thermophilic temperatures. *Appl. Microbiol. Biotechnol.* 43: 346-350.
- McInerney MJ, Bryant MP (1981). *Fuel Gas Production from Biomass*(ed. Wise, D. L.), Chemical Rubber Co. Press Inc., West Palm Beach, Florida, pp. 26-40.
- Milono P, Lindajati T, Aman S (1981). Biogas production from agricultural organic residues. In the first ASEAN seminar-workshop on Biogas Technology, working group on food waste materials. pp. 52-65.
- Momoh Y (2004) "Biogas Production from the Co-Digestion of Cow Dung, Paper Waste and Water Hyacinth", M.Sc. Thesis in Environmental Engineering, University of Port Harcourt.
- Mshandete AM, Parawira W (2009). Biogas technology research in selected sub-Saharan African countries - A review. *Afr. J. Biotechnol.* 8: 116-125
- Nagamani B, Ramasamy K (2007) "Biogas Production Technology: An Indian Perspective" Fermentation Laboratory, Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore 641 003, India
- Parawira W, Murto M, Zvauya R, Mattiasson B (2004). Anaerobic digestion of solid potato waste alone and in combination with sugar beet leaves. *Renew. Energy* 29: 1811-1823.
- Pillaiyer P (1988). "RICE: Post Production Manual", Wiley Eastern Limited New Delhi, India.
- Pualchamy C, Dharmaraj P, Laxmanan U (2008). A preliminary study on co-digestion of ossein industry waste for methane production. *EurAsia J. BioSci.* 2: 110-114.
- Rozainee M, Ngo SP, Salema AA, Tan KG (2008); "Study on the quality of rice husk ash at different fluidizing velocity in a fluidized bed combustor", *J. Solid Waste Technol. Manage.* 34:1-6
- Saev M, Koumanova B, Simeonov IV (2009). Anaerobic co-digestion of wasted tomatoes and cattle dung for biogas production. *J. Univ. Chem. Tech. Mtlgy.* 44: 55-60.

- Ueda T, Kunimitsu Y, Shinogi Y (2007). "Potential conflicts for the re-use of rice husk in Thailand", *Paddy and Water Environ.* 5 (2): 123-129
- Uzodima EO, Ofoefule AU, Eze JI, Onwuka ND (2007). Biogas production from blends of agro-industrial wastes. *Trends Appl. Sci. Res.* 2: 554-558.
- Uzodima EO, Ofoefule AU, Eze JI, Mbaeyi, I, Onwuka ND (2008). Effect of some organic wastes on the biogas yield from carbonated soft drink sludge. *Sci. Res. Essay*, 3(9): 401-405.
- Vicenta M, Pacheco G, Alamis MLA, Anglo PG, Tan BV, Silverio CM (1984). A study of some factors affecting biogas production from pineapple peelings. In: Bidin R, Chong CN, Wang CW (Eds.). *Proceedings of the second ASEAN Workshop on biogas production applied to the management and utilization of food waste materials.* Kuala Terengganu, Malaysia. Pp. 189-202.
- Vigil S, Theisen H, Tchobanoglous G (1993). *Integrated Solid Waste Management Engineering Principle and Management Issues.* McGraw-Hill Inc. Singapore.
- Zhang R, Zhang Z (1999). Bio-gasification of rice straw with an anaerobic-phased solids digester system. *Bioresour. Technol.* 68: 235-245.