African Journal of Pig Farming Vol. 1 (2), pp. 023-027, October, 2013. Available online at www.internationalscholarsjournals.org

Full Length Research Paper

Biodigestion of cassava peels blended with pig dung for methane generation

Oparaku, N. F., Ofomatah, A. C* and Okoroigwe, E. C.

National Center for Energy Research and Development, University of Nigeria, Nsukka, Enugu State, Nigeria.

Accepted 16 September, 2013

Biogas production from cassava (*Manihot esculentus*) peels and pig dung under a mesophilic temperature condition was investigated. Three blends of the wastes and a control labeled as B1, B2, B3 and C representing blend 1 (50:50 peel/dung), blend 2 (30:70 peel/dung), blend 3 (10:90 peel/dung) and control (pig dung alone) were used, respectively. Biodigestion of the wastes blends and control was carried out simultaneously under the same environmental and operational conditions of 30 days retention period using four metallic biodigesters of 32 L capacity each. The biogas yield result shows that blend 2 yielded the highest cumulative biogas of 78.5 L, while the least yield of 61.7 L was obtained by blend 3. When compared with the control set up and biodigestion of cassava waste alone from literature, there was blending effect resulting in increase in yield of biogas over the sole digestion of cassava peel or pig dung. Methane production leading to the combustibility of the biogas started at 6th, 5th, 5th and 4th days for B1, B2, B3 and C, respectively. This, in agreement with earlier studies show that better handling of cassava peels for energy production would be achieved by blending it with animal wastes in the right proportion.

Key words: Cassava peel, biogas, co-digestion, anaerobic digestion, wastes blends, lag days.

INTRODUCTION

One of the main environmental problems of today's society is the continuous increase in production of organic wastes which are harmful to human existence. In many developing countries, sustainable waste management and reduction have become major issue due to lack of adequate technology and methodology to handle wastes generated from daily living activities. Some of the waste types which are posing serious environmental threats to human and animal existence in these nations come from agriculture due to their degradable nature and lack of profitable technique to convert these 'wastes' to better manure quality or other useful means such as energy. With increase in farm (agricultural) operations, greater waste production is proposed.

Cassava is one of the major root crops produced in sub-Saharan Africa. World cassava production in 2002 was estimated at 184 million tonnes (Odoemenem and Otanwa, 2011). As at 2002, Africa exported only one ton of cassava annually (FAO, 2001) but by 2007, out of "more than 228 million tonnes of cassava produced worldwide, Africa accounted for 52% and Nigeria produced 46 million tons making it the world's largest producer of cassava" (IITA -1). It has been projected that total world cassava utilization would hit 275 million tons by 2020 (IFPRI, 2008; Arowolo and Adaja, 2012) while some researchers estimate this number closer to 291 million tons.

Currently, there is increase in campaign for enlarging the cassava production scale in Nigeria. The implication of this is increased waste production from cassava processing. According to FAO (2001), about 250 to 300 kg of cassava peels is produced per tonne of fresh cassava

*Corresponding author. E-mail: ofomatony@yahoo.co.uk. Tel: +2348034010807.

root processed. This suggests huge sum of waste production in form of peels from cassava production and processing. Hence, there is need to design and adopt a system capable of handling the huge waste accruing from this development and anticipated problems such as unpleasant odour production.

One of the ways by which cassava peels can be managed in addition to using it as animal diet (Okeudo and Adegbola, 1993) is by anaerobic digestion for methane and bio-fertilizer production. From the literature, it is obvious that attempts have been made to convert cassava peels to energy. Adeyanju (2008) demonstrated the effect of adding wood ash to the biodigestion of mixture of piggery wastes and cassava peels in a laboratory scale. It was found that the wood ash addition increased the biogas production of either the biodigestion of piggery wastes and cassava peels only or in combination of both wastes in different proportions. The period it takes to produce methane was not stated probably because it was only a laboratory set up. Ofoefule and Uzodimma (2009) compared the biogas production potential of cassava peels alone to the blends of the waste with animal wastes. It was found that cassava peels alone produced a total of 68.70 L of biogas which could burn after 58 days of digestion. When blended with cow dung, poultry droppings and pig dung, the volume of biogas produced increased to 146.5, 166.50, and 169.60 L, respectively, while the flammable gas was produced after 9 days in the first 2 and 11 days in the later. These imply that anaerobic digestion of cassava peels alone is by no means economical. However, in this work, the blending with animal waste was on equal ratio. The effect of different mix ratios in biogas production potential and flammability of the biogas is a gap to be filled up by further investigation. Ezekoye and Ezekoye (2009) combined cassava peels with rice husk in the ratio of 1:5 for biodegradation of the wastes. It is also gathered that this set up was inoculated with cow dung mixed with water. From the result, flammable biogas was produced after 30 days with a total of volume of 3.450 m^3. It is not certain which of the substrates is responsible for the long retention period of 70 days and large volume of biogas recorded. However, it is obvious that combination of two plant biomass is not a favourable combination in anaerobic digestion since animal protein is important for microbial activity of the methanogens.

Adelekan and Bamgboye (2009) have done a more detailed investigation from the existing works. The biogas productivity of cassava peels mixed in different ratios with fixed amount of animal wastes was investigated. In this work, 1, 2, 3 and 4 parts of cassava peels were mixed with one part each of poultry, piggery and cattle wastes. It was found that there was statistically significant effect of the mix ratios over biogas production. In this work also, it was found that the equal mass combination in all the animal waste types produced the highest biogas by volume when compared with other ratios. The effect of mix ratios on how long it takes to produce flammable biogas was not covered.

Combination of cassava waste with other biomass species of agricultural origin has continued to attract the interest of scholars. In addition to the above, Ilaboya et al. (2010) blended cassava peels with pineapple and plantain peels in a laboratory set up. One of the aims of their work was to monitor the effect of alkaline addition to the substrate in biogas generation potential of the mixture. It was observed that addition of NaOH (alkaline) solution resulted in increase in biogas production over no alkaline addition. Also, there was positive effect in increase of biogas generation by different ratios of alkaline mixture. However, this work did not also address the effect of mixing the cassava peels in different ratios of other wastes.

In order to fill some gaps existing in previous co-digestion of cassava peel with other waste types, there is need to study the effect of varying the mix ratio of cassava peels vis-a-vis mix ratio of other wastes. In this work, quantity of cassava peel is varied with varying quantity of piggery dung in a batch anaerobic digestion. It is aimed at determining the mix combination that will yield the largest volume of biogas and the number of days it would take to produce flammable biogas while working with a particular waste. However, varying cassava peels in blends of multiple animal waste types can be investigated in another work.

Biodigestion of agricultural wastes is important as a way of maximizing the output of agricultural practice of developing nations. Multiple products (benefits) can be derived. This includes energy and biofertilizer production. It has been found that biodigestion of agricultural wastes produces better manure than using the wastes as raw manures in farm practice (Okoroigwe, 2007; Okoroigwe et al., 2008).

MATERIALS AND METHODS

The raw materials (cassava peels and the piggery waste) were obtained within University of Nigeria, Nsukka in Enugu State of Nigeria. Prior to the biodigestion of the wastes, the cassava peels were partially fermented by soaking in water for 7 days in order to reduce the acid content of cassava peels which could be detrimental to the microbes. Cyanide is an inhibitor to microbial activities (Cuzin and Labat, 1992; Cuzin et al., 1992). Standard methods were used to determine the proximate (moisture, ash) and chemical analyses of the samples prior to digestion. The cassava peels and the piggery dung were mixed in the ratio of 50% by weight of cassava peels to 50% by weight of piggery dung. This serves as blend 1 (B1). The second and third blends were achieved by 20% reduction and 20% increase in weight of cassava peel and piggery dung, respectively, in preceding blend. Hence, B2 and B3 were 30:70 and 10:90 (cassava peels: piggery dung), respectively. A control set up contained only piggery dung mixed with water at equal weight. All the samples were added with equal weight of water to the combined weights of the waste types. This is required to achieve 5 to 10% total solids (TS) concentration. The set up was monitored for daily gas production by measuring the volume of gas using downward displacement method. In order to achieve

Table 1. Proximate composition and physicochemical properties of the various wastes.

Parameter	Composition (%)			
	B1	B2	B3	C
Crude protein	2.89	3.23	3.57	3.74
Crude fat	1.17	0.87	0.57	0.42
Crude fibre	1.17	0.87	15.05	0.42
Ash	18.45	18.79	19.13	19.30
Moisture	26.65	21.79	16.93	14.50
Carbohydrate	37.69	41.22	44.75	46.52
Total solids	63.43	67.86	72.29	74.50
Volatile solids	35.00	35.07	35.15	35.19
Carbon	22.72	21.22	19.71	18.96
Nitrogen	0.46	0.52	0.87	0.60
C:N	49	41	23	32

homogeneity of the slurry and discourage scum formation in the system, daily stirring was carried out using the inbuilt stirring mechanism in the digesters.

Both slurry and ambient temperatures were measured at morning and afternoon hours. The average of both readings for any day becomes the reported slurry or ambient.

RESULTS AND DISCUSSION

The physico-chemical parameters of the waste streams are presented in Table 1. It shows that these wastes are good bioresources for methane generation. These values are close to values obtained by other researchers. The values however differ slightly because different waste combinations will give different composition of nutrients. It has been shown that biogas yield from AD of wastes depends on a number of factors such as pH, HRT and CN ratio (Yadika et al., 2004). CN ratio is an important indicator for controlling biological treatment systems (Wang et al., 2012). It has been pointed out that high C/N ratio indicates rapid nitrogen consumption by methanogens and leads to lower gas production while low C/N ratio results in ammonia accumulation and an increase in pH values, which is toxic to methanogenic bacteria (Zhang et al., 2013). This is partly reflected in the biogas yield of the blends as B3 with the lowest C/N ratio yield the least gas among the blends and the B1 with largest C/N ratio yields moderate biogas as compared to B2 according to the explanation above but Yadika et al. (2004), pointed out that during anaerobic digestion, microorganisms utilize carbon 25 to 30 times faster than nitrogen. Thus, to meet this requirement, microbes need a 20 to 30:1 ratio of C to N. This may justify the values presented in Table 1 as good for biogas generation.

The pH of the blend substrates and the control are presented in Figure 1. The result shows that the range of the pH values was 5 to 7.3 from the 3rd day to the 30th day. It shows that the B1 and C had initial acidic condition. This agrees with Zhang et al. (2013) explanation on relationship between high C/N ratio and toxicity of the reacting medium. Similarly, the pH values of other blends were responsible for the high biogas yield experienced by B2 and B3. Figure 1 also shows that the reactions in all the blends and control have initial acid condition which neutralized as the reactions progressed to the 30th day.

Table 2 presents the cumulative biogas yield of the different blends and the control, while Figure 1 shows daily biogas production pattern of the waste blends and the control. From the result, blend 2 (B2) yielded the largest quantity of biogas (78.5L) followed by B1 (73.5L) while the least yield of 61.7L was obtained from the 3rd blend (B3). When compared with the control set up of biodigestion of piggery dung alone, there was blending effect leading to the increase in biogas yield. This shows that anaerobic digestion of piggery waste can be enhanced by combination with other wastes such as plant biomass. The result is different if combustibility of the generated gas is of interest. Biogas is not useful if it cannot be burnt in a combustor for energy and power production. Even though, the lag day (period to produce flammable gas) is shortest in the control experiment, it is necessary to blend it with other wastes as there is not much difference in the lag day of B2 which produced the largest volume of biogas. The low volume of biogas in biodigestion of pig dung alone is due to high concentrations of NH_4-N which inhibits the process of degradation of organic matter, causing a decrease in volume of biogas produced.

When compared with literature value of anaerobic digestion (AD) of cassava peels only, the least blending yield of 61.7 L (B3) obtained in this work was close to 68.70 L obtained by Ofoefule and Uzodimma (2009). The higher yield however, could be because of larger volume of biodigester and pretreatment used by them. But it has been pointed out that cassava peels alone is a poor feedstock for AD due to its high acid content (Cuzin and Labat, 1992; Cuzin et al., 1992). The results obtained here conform with other reports from other scholars (Adeyanju, 2008; Adelekan and Bamgboye, 2009) showing blending effect. This result has shown that blending the cassava peel with animal wastes should be better done at co-variation of both waste types to obtain an optimum mix ratio that will yield larger volume of gas.

The effect of microbial load (Table 3) can be observed in the pH stabilization (Figure 2) as the reactions progressed from 6th to 30th day. The multiplication of microbes in the system from 6th to 21st day is responsible for acid neutralization as there was progressive consumption of nutrients in the substrates. This was also responsible for the increase in the biogas yield in all the blends as microbial count increased. The peak production of biogas (Figure 1) is observed around the 21st day in blend 2 due to peak microbial count about that

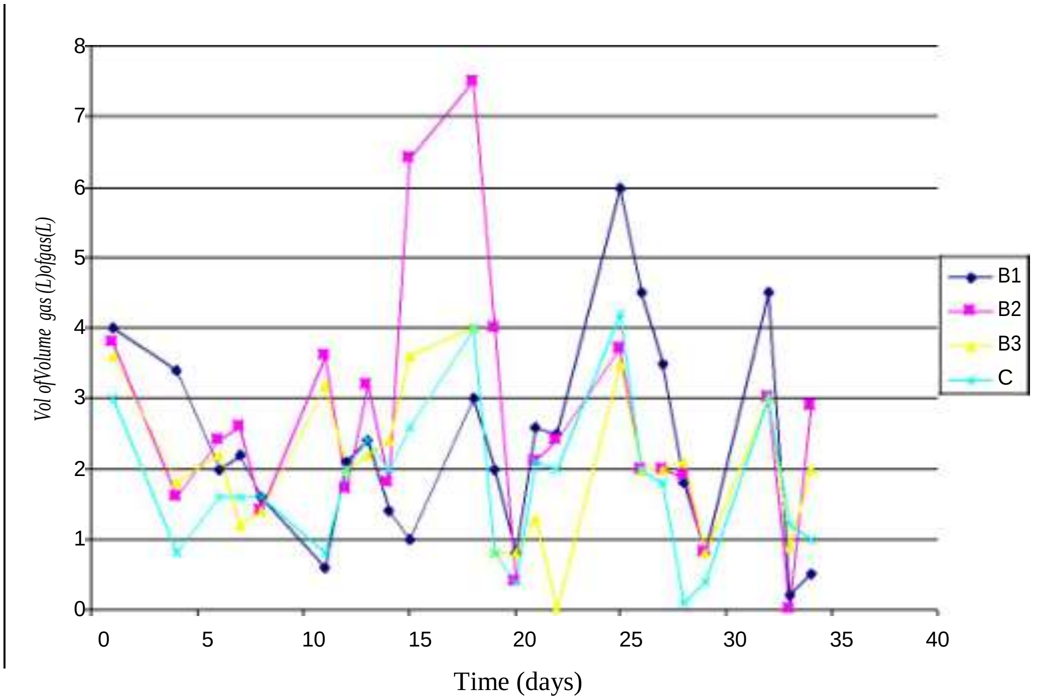

Figure 1. Daily biogas production pattern in the wastes.

Table 2. Cumulative biogas yield pattern of the wastes.

Parameter	Value			
	B1	B2	B3	C
Lag days	6	5	5	4
Cum biogas yield (L/gS)	73.50	78.5	61.7	55.1
Mean biogas yield	2.45	2.62	2.05	1.83

Table 3. Microbial load of the different waste blends.

Day	Microbial count ($x10^4$)			
	B1	B2	B3	C
1	2.0	2.2	1.9	1.9
6	2.2	2.3	2.1	2.0
11	2.3	2.5	2.3	2.2
16	3.8	3.9	3.2	3.0
21	2.0	22.0	1.3	12.0
26	3.2	3.3	2.2	2.0
30	2.5	1.7	1.9	1.9

time (Table 3). The microbial load began to reduce from the 21st day until the 30th day due to extensive consumption of nutrients in all the blends as well as in the control.

Figure 3 shows the temperature distribution pattern in both waste slurries and the ambient. The temperature values were with 25 to 35°C in all cases within the 30 day test period. This is a mesophilic temperature range which enabled the micro-organisms to thrive favourably in the system for maximum performance. It therefore means that the volumetric result of biogas production is at its utmost yield condition.

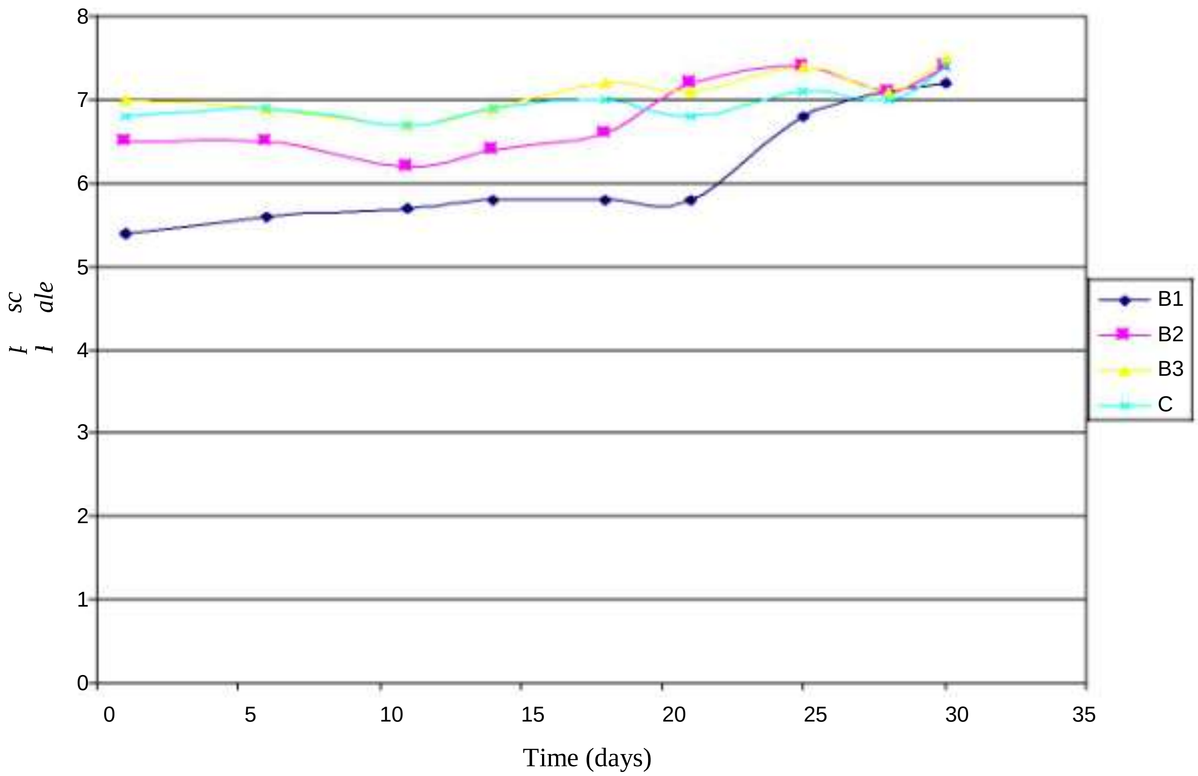

Figure 2. pH variation in the wastes.

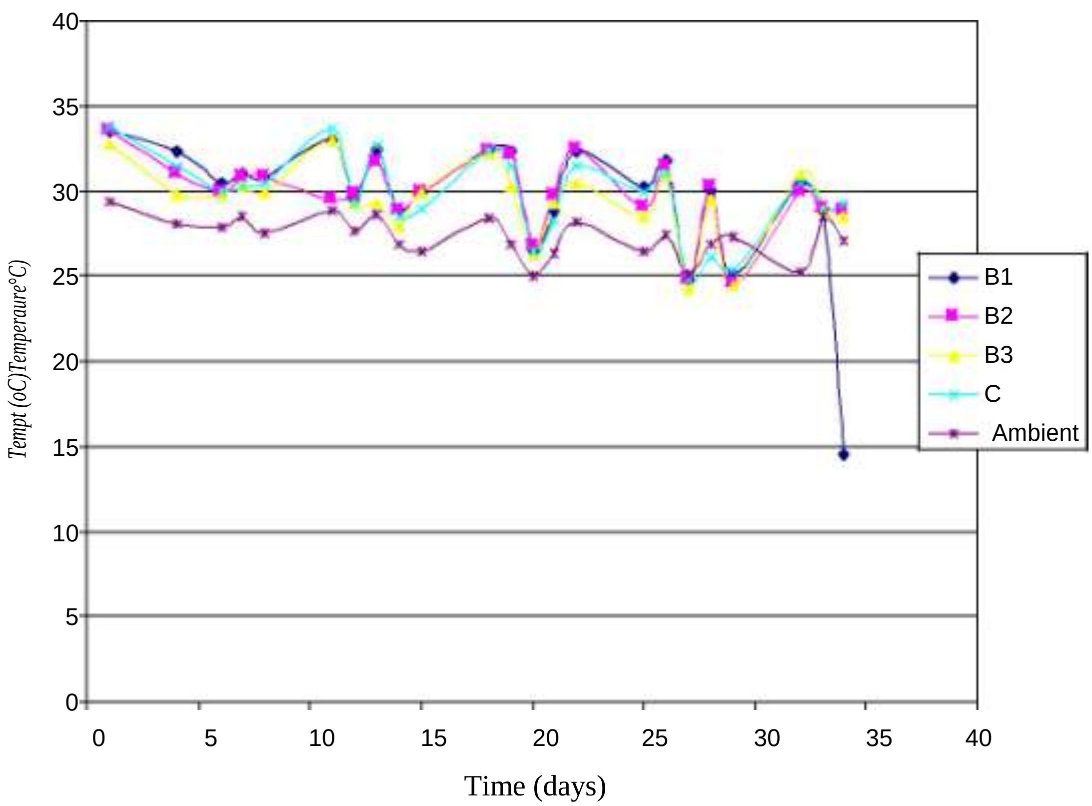

Figure 3. Average slurry and ambient temperature variation.

Conclusion

In this work, co-biodigestion of cassava peels with piggery waste was carried out in varying quantities of both wastes; there was blending effect over single biodigestion either of the plant and animal wastes. The B2 blend showing the combination of 30% by weight of plant waste (cassava peels) with 70% by weight of animal waste (piggery dung), yielded the largest volume of biogas on cumulative basis. Flammable biogas (methane rich biogas) was produced on the 5th day even though biodigestion of piggery waste alone produced flammable biogas on the 4th day. The blending improved the methane production of cassava peels alone from about 59 days (literature value) to five days in combination with piggery dung.

REFERENCES

Adeyanju AA (2008). Effect of Seeding of Wood-Ash on Biogas Production Using Pig Waste and Cassava Peels. J. Eng. Appl. Sci. 3(3):242-245.

Arowolo AA, JI Adaja (2012). Investigation of Manihot Esculenta and Manihot Duleis Production in Nigeria: An Econometric Approach. J. Appl. Sci. Environ. 3:18-24.

Cuzin N, Farinet JL, Segretain C, Labat M (1992). Methanogenic Fermentation of Cassava Peel Using a Pilot Plug Flow Digester. Bioresour. Technol. 41:259-264.

Cuzin N, Labat M (1992). Reduction of Cyanide Levels During Anaerobic Digestion of Cassava. Int. J. Food Sci. Technol. 27:329-336.

Ezekoye VA, Ezekoye BA (2009). Characterization and Storage of BiogasProduced from the Anaerobic Digestion of CowDung, Spent Grains/Cow Dung, and CassavaPeels/Rice Husk. Pac. J. Sci. Technol. 10(2):898-904.

FAO (2001). Proceedings of The Validation Forum on The Global Cassava Development Strategy. Food and Agriculture Organization of the United Nations International Fund for Agricultural Development Rome, 2001. p. 65.

IFPRI (2008). Reaching sustainable food security for all by 2020. Getting the priorities and responsibilities right. International Food Policy Research Institute, Washington, D.C: IFPRI. In Aeowolo and Adaja, 2012

IITA -1 (http://www.iita.org/cassava, assessed 3/9/2013).

Ilaboya IR, Asekhame FF, Ezugwu MO, Erameh AA, Omofuma FE (2010). Studies on Biogas Generation from Agricultural Waste; Analysis of the effects of alkaline on gas generation. World Appl. Sci. J. 9(5):537-545.

Ofoefule AU, Uzodinma EO (2009). Biogas production from blends of cassava (*Manihot utilissima*) peels with some animal wastes. Int. J. Phys. Sci. 4(7):398-402.

Okeudo NJ, Adegbola AA (1993). Utilisation of dried caged-hen manure and cassava peels for intensive sheep production. Trop. Anim. Health Prod. 25(4):234-238

Okoroigwe EC (2007). Application of Biomass Technology in Sustainable Agriculture. Trends Appl. Sci. Res. 2(6):549-553.

Okoroigwe EC, Eze JI, Oparaku OU (2008). Field Comparison of Biofertilizer and Chemical Fertilizer Application on Maize Production. Niger. J. Solar Energy. 19(1):55-57.

Wang X, Yang G, Feng Y, Ren G, Han X (2012) Optimizing feeding composition and carbon-nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw. Bioresour. Technol. 120:78-83

Yadvika, Santosh, Sreekrishnan TR, Kohli S, Rana V (2004). Enhancement of biogas production from solid substrates using different techniques -a review. Bioresour. Technol. 95:(1)1-10.

Zhang T, Liu L, Song Z, Ren G, Feng Y, Han X , Yang G (2013). Biogas Production by Co-digestion of Goat Manure with Three Crop Residues. PLoS ONE 8(6): e66845. doi:10.1371/journal.pone.0066845.