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Biogas production from blends of bambara nut (*Vigna subterranea*) chaff with some animal and plant wastes

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ABSTRACT

A study on the biogas production from blends of Bambara nut (Vigna Subterranea) chaff (BNC) with some animal and plant wastes was carried out. The wastes were blended as Bambara nut chaff and Cow dung (BNC: CD), Bambara nut chaff and Swine dung (BNC: SD, Bambara nut chaff and Cassava peels (BNC: CP) and Bambara nut chaff and field grass (BNC: FG) all in the ratio of 1:1, while the BNC alone served as control. The wastes were charged into 50L capacity metal prototype digesters in the ratio of approx. 3:1 of water to waste. The moisture content of the wastes determined the water to waste ratio. The anaerobic digestion was operated under a mesophilic temperature range of 23 - 37°C within a 19 day retention period. Results obtained showed that the BNC alone had a cumulative biogas yield of 3.16dm^3/kg. slurry with mean volume of 0.16±0.12dm^3/kg. slurry and onset of gas flammability on the 10th day. When blended with the animal and plant wastes, the cumulative biogas yield was increased to 3.30dm^3/kg. slurry with mean volume of 0.17±0.15dm^3/kg. slurry and 3.27dm^3/kg. slurry with mean volume of 0.17± 0.13dm^3/kg. slurry for the BNC: CD and BNC: SD respectively while the yield decreased to 2.87 dm^3/kg. slurry with mean volume of 0.15±0.06dm^3/kg. slurry and 2.23dm^3/kg. slurry with mean volume of 0.12±0.13 dm^3/kg. slurry for the BND: CP and BNC: FG respectively. All the blends commenced flammable gas production within 24 hr of charging the digesters, however, the gas flammability was not sustained and gas production stopped entirely after the 19th day. General results show that blending the Bambara nut with these animal and plant wastes did not improve its gas production parameters in terms of yield, sustained gas flammability / production and retention time. Overall results indicate that the waste requires chemical treatment to improve its gas production capability since it was found to be acidic throughout the period of digestion.

Key words: Bambara nut chaff, waste blends, Biogas production, gas flammability, biogas yield, retention time.

INTRODUCTION

Since the world's energy crisis of the 1970's, developing alternative sources of energy especially from renewable sources has become very paramount. Biogas is viewed as one of such renewable alternative sources derived from plants that use solar energy during the process of photosynthesis. Biogas is a colourless, flammable gas produced via anaerobic digestion of biogenic wastes to give mainly methane (50-70%), CO_2 (20-40%) and traces of other gases such as H_2S, NH_3, CO, N_2, H_2, O_2 and water vapour etc.[1]. The composition of the gas depends on the source of feedstock and the management of the digestion process [2]. The gas becomes flammable when the methane content is at least 45% [3]. Biogas production is a three stage complex biochemical process that takes place under anaerobic conditions in the presence of highly pH sensitive biocatalysts that are mainly bacteria. The process involves solublization (hydrolysis), acidification (Acidogenesis / Acetogenesis) and methane formation (methanogenesis). The methanogens also operate within three temperature ranges namely; Psychrophilic temperature (< 25°C), mesophilic (25-40°C) and thermophilic (45-60°C) [4]. Potentially, all organic waste materials contain adequate quantities of the nutrients essential for the growth and metabolism of anaerobic bacteria in biogas production. However, the chemical composition and biological availability of the nutrients contained in these materials vary with species, factors affecting growth and the age of the animal or plant [5].

Biogas technology amongst other processes (including thermal, pyrolysis, combustion and gasification) has in recent times also been viewed as a very good source of sustainable waste treatment /management as disposal of wastes has become a major problem especially to the third world countries [6]. The effluent of this process is a residue rich in essential inorganic elements like nitrogen and phosphorus needed for healthy plant growth known as biofertilizer which when applied to the soil enriches it with no detrimental effects to the environment [7]. Several organic wastes have been exploited for biogas production as reported in literature and they include amongst others; animal wastes [8], plant wastes [9], [10], Industrial wastes [11] food processing wastes [12] etc.

Plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of the difficulty in achieving hydrolysis of cellulosic and ligninic constituents [13] with attendant acidity in the biogas systems leading to reduction and sometimes cessation of gas flammability / gas production [14], [15] etc.

Further researches on many locally available wastes especially plant residues as potential feedstocks for biogas production are still on going. Bambara nut chaff is one of such locally available wastes viewed as a potential feedstock. Bambara nut chaff is obtained from Bambara nut (*Vigna subterranea*) which is grown in the Northern part of Nigeria and other parts of West Africa like Cameroon [16]. It is largely consumed in the northern part of Nigeria. The processing leaves the chaff which is either used as blend for poultry feed by some people or thrown away, thereby constituting a nuisance to the environment. Previous study carried out on the biogas production potentials of Bambara nut chaff showed that it had potentials for biogas production but the gas flammability could not be sustained as a result of the death of the methanogens due to acidity of the system [17]. This also led to the cessation of the total biogas production giving an effective retention time of 19 days. The study concluded that the waste would require some form of treatment/pretreatment/ blending with animal wastes to enhance its production capability.

Several optimization techniques for enhancing biogas production exist which include blending, size reduction, inoculation, chemical treatment, addition of metals etc. [18], [19]. This study was undertaken to investigate the effect of blending the Bambara nut chaff with some animal and plant wastes on the biogas production in terms of effective retention time, onset / sustained flammable biogas production and cumulative biogas yield. They were blended as; Bambara nut and Cow dung (BNC: CD), Bambara nut chaff and Swine dung (BNC: SD), Bambara nut chaff and cassava peels (BNC: CP) and Bambara nut chaff and Field grass (BNC: FG) all in the ratio of 1:1 while the Bambara nut chaff alone (BNC) served as the control.

MATERIALS AND METHODS

The Bambara nut chaff used for this study was obtained from a local processor of Bambara nut flour (a staple food in the north eastern part of Nigeria). The Cow dung was procured from an abattoir at Nsukka town while the swine dung was procured from the veterinary farm, University of Nigeria, Nsukka. The cassava peels were obtained from a local processor of "garri" (Staple food in the eastern part of Nigeria) while the field grass was collected from the compound of the National Center for Energy Research and Development, University of Nigeria, Nsukka. The five digesters used are of metal prototype (50L capacity) constructed at the National Center for Energy Research and Development, University of Nigeria, Nsukka (Fig. 1) and the study was carried out between June and July, 2009 at the same Research Institute. Nsukka is located 6.9°N and 7.4°E and 445m above sea level. Other materials used include; top loading balance (50kg capacity, "Five Goats" model no Z051599), plastic water bath for soaking the plant wastes, water trough, graduated transparent plastic bucket for measuring volume of gas production, thermometer (-10-110°C), digital pH meter (Jenway, 3510), hosepipe, biogas burner fabricated locally for checking gas flammability.

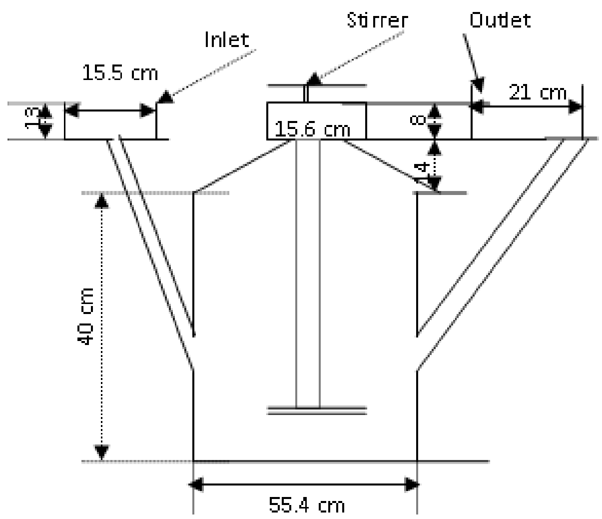

Fig. 1: Schematic diagram of the biodigester

Digestion Studies

Preparation of Wastes

The plant wastes were allowed to dry up and degrade for about one month to reduce the toxicity of the waste due to acidity. They were then cut into small sizes (about 2") for ease of stirring while inside the digester and better reaction due to size reduction. They were subsequently soaked in water at 50% level for two weeks to allow for partial decomposition of the waste by aerobic microbes which have been reported to facilitate cellulosic breakdown [20]. After the soaking period, the wastes were then weighed out for charging. For the BNC alone 8kg of the BNC was mixed with 27kg of water. For the blends, 4kg each of the Cow dung (CD), swine dung (SD), cassava peels (CP) and Field grass (FG) was blended with 4kg of the BNC in the ratio of 1:1. They were then mixed with water (27kg) for each of the digesters. All the variants gave water to waste ratio of approx. 3:1. The moisture content of the wastes determined the water to waste ratio.

Charging of Digesters

The five digesters were charged separately into the different digesters. They were charged up to ¾ of the digester leaving ¼ head space for gas storage and collection. The digester content was stirred adequately and on a daily basis throughout the retention period to ensure homogenous blend of the wastes and dispersion of the microbes in the entire mixture. Gas production measured in dm^3/kg. slurry was obtained by the downward displacement of water by the gas.

Analyses of Wastes

Physicochemical Analyses

Ash, moisture and fiber contents were determined using AOAC (1990) method [21]. Fat, crude nitrogen and protein contents were determined using Soxhlet extraction and micro-Kjedhal methods described in Pearson (1976) [22]. Carbon content was carried out using Walkey and Black (1934) method [23], Energy content was carried out using the AOAC method described in Onwuka (2005) [24] while Total and Volatile solids were determined using Renewable Technologies (2005) method [25].

Biochemical Analysis

The pH of waste was monitored using digital pH meter (Jenway, 3510). Ambient and slurry temperatures were also monitored and recorded daily using liquid in glass thermometer (-10 to 110^oC).

Microbial Analysis

Microbial Total viable counts (TVC) for the waste slurry was carried out to determine the microbial load of the sample using the modified Miles and Misra method as described in Okore (2004) [26]. This was carried out at four different periods during the digestion; At the point of charging the digester, at the point of flammability, at the peak of gas production and at the end of the retention period.

Statistical Analysis

The standard deviation was carried out using SPSS 15.0 version.

RESULTS AND DISCUSSION

The experiment was carried out under mean ambient temperature range of 23°C-33°C and influent temperature range of 24°C-37°C. The daily biogas production of the wastes is graphically presented in Fig. 2. The study was carried out under an effective retention period of 19 days since that was the day of cessation of gas production. The result of the pH monitoring throughout the retention period is shown in Fig. 3. The physicochemical properties of the wastes are shown in Table 1. The Lag period, Cumulative and mean volume of gas production are shown in Table 2, while the microbial total viable count (TVC) is shown in Table 3. All the digesters commenced biogas production within 24hr of charging the digesters. The BNC alone had a cumulative biogas yield of 3.16dm^3/kg. slurry. This yield was lower than that obtained in the previous investigation of the waste (which was 3.92dm^3/kg. slurry) within the same retention period of 19 days [17]. This observation may be accounted for by reason of the period the study was undertaken. Methanogens are known to be temperature sensitive and digestion studies undertaken during the cold or rainy seasons would generally produce lower volume of gas than those undertaken during the hot or sunny seasons [27], [9]. Since this study took place at the peak of rainy season, it may be responsible for the drop in volume as Fig. 2 shows that there was no gas production on the 18th day due to the heavy rain on that day. The result of the physicochemical properties shows that BNC has adequate properties to produce more biogas than observed, however, as reported in the previous work, the poor performance was attributed to two factors; i) The carbon to nitrogen (C/N) ratio which fell bellow the optimum range required for effective biogas production which has been given to be in the range 20-30:1 [28]. This is because the microbes that convert wastes to biogas take up carbon approx. 30 times faster than nitrogen for their growth. ii) The low pH. Fig. 3 shows that the pH of the wastes for the period monitored were mainly acidic. These observations confirm the results of the previous investigation.

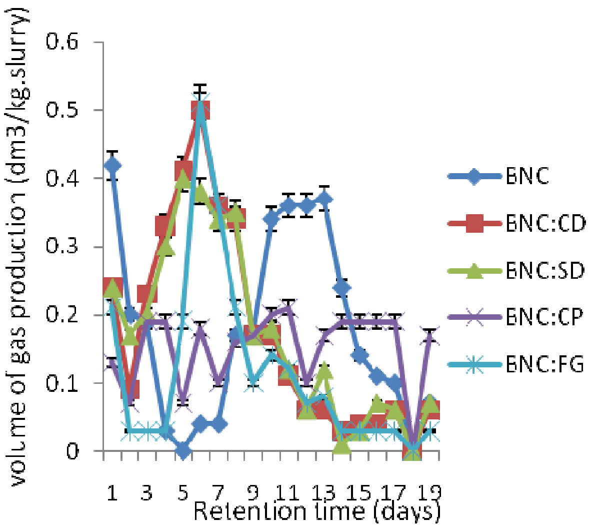

Fig. 2: Daily biogas production for the wastes

Blending of wastes has been known to be not only good optimization technique but also a good way of stabilizing the wastes for biogas production [11], [15]. However, the result of the study showed that for Bambara nut chaff, blending alone did not accomplish the expected waste stabilization. When BNC was blended with cow dung, swine dung, cassava peels and field grass, the cumulative biogas yield was not improved significantly (Table 2). In fact, the blend with the plant wastes performed below that of the BNC alone. The systems were mainly acidic throughout the retention period (Fig. 3) and may have affected the production capabilities during the digestion. The BNC: CD gave the highest biogas yield followed by the BNC: SD. The blending appeared to be effective in improving the lag period (which is from the time of charging the digester to the onset of gas flammability). All the blends became flammable in less than 24hr post charging period and the result of the TVC in Table 3 showed that the microbial load was very high at the point of charging the wastes. In fact, no waste so far reported has been able to commence gas flammability in such a short period. Even though the digester systems commenced flammability when the pH was low, this could not be sustained. Within a short period, the gas production dropped sharply and stopped all together. This observation confirms reports by literature that methanogens do not survive at low pH (acidic). The optimum pH range has been given to be in the range 6.5-8.0 [29], [30]. This also affected the retention period. Minimum retention period for good feedstock for biogas production has been reported to be between 25-30 days. Some higher biogas producers like cow dung have up to 60 days retention time [31]. Optimization through blending of wastes for stabilization, effective and efficient biogas production was expected to improve the retention time. This however did not take place in the present study. Blending also improved the C/N ratio of the wastes (Table 1). The C/N ratios were within the optimum range required for effective gas production; however, this did not translate to a significant increase in biogas yield.

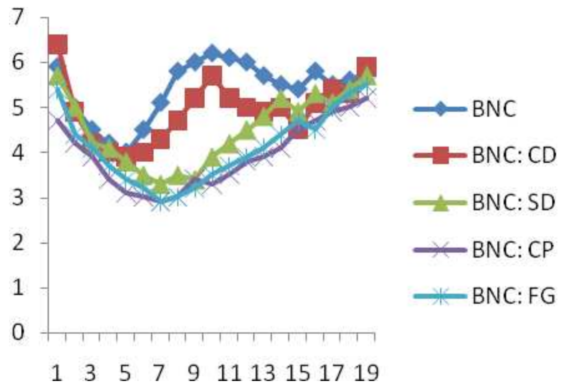

Fig. 3: pH monitoring during the digestion

The important physicochemical properties that affect biogas production- nutrients, volatile solids (which is the biodegradable portion of the waste), C/N ratio and Energy were quite high but these did not also translate to higher cumulative gas yields for the blends. This indicates that the pH problem of the waste needed to be addressed through chemical treatment.

Table 1: Physicochemical Properties of the wastes

Parameters	BNC	BNC: CD	BNC: SD	BNC: CP	BNC: FG
Moisture (%)	19.6	51.2	29.8	9.6	9.4
Ash (%)	18.6	26.25	25.62	37.03	12.51
Fibre (%)	36.40	16.40	31.15	47.65	41.95
Fat (%)	2.3	1.2	1.2	1.3	2.1
Crude protein (%)	14.73	9.46	9.6	12.36	10.52
Crude nitrogen (%)	2.36	1.51	1.54	1.98	1.68
Total solids (%)	80.40	48.80	70.20	90.40	90.60
Volatile solids (%)	61.80	22.55	44.58	53.37	78.09
Carbon (%)	46.86	36.45	46.45	51.58	43.84
Energy (Kcal/g)	3.46	3.61	3.15	3.28	3.51
C/N ratio	19.86	24.14	30.16	26.05	26.10

BNC=Bambara nut, CD=Cow dung, SD= Swine dung, CP=Cassava Peels, FG= Field grass.

Table 2: Lag period, cumulative and Mean volume of gas production

Parameters	BNC	BNC: CD	BNC: SD	BNC: CP	BNC: FG
Lag period (days)	10	< 1	< 1	< 1	< 1
Cumulative volume (dm^3/kg. slurry)	3.16	3.30	3.27	2.87	2.23
Mean volume (dm^3/kg. slurry)	0.16± 0.12	0.17± 0.15	0.17±0.13	0.15± 0.06	0.12± 0.13

BNC=Bambara nut, CD=Cow dung, SD= Swine dung, CP=Cassava Peels, FG= Field grass.

Table 3: Microbial Total Viable Count (TVC) (cfu/ml)

Parameters	BNC	BNC: CD	BNC: SD	BNC: CP	BNC: FG
At Charging	$5.69X10^9$	$2.07X10^9$	$1.84X10^9$	$2.38X10^9$	$4.88X10^9$
At flammability	$3.05X10^8$	$2.27X10^8$	$1.67X10^7$	$1.77X10^6$	$1.27X10^6$
At the peak of production	$2.38X10^8$	$2.10X10^6$	$1.07X10^5$	$1.31X10^4$	$1.16X10^5$
At the end of the retention period	$1.06X10^6$	$9.33X10^3$	$4.67X10^4$	$4.23X10^2$	$6.18X10^3$

BNC=Bambara nut, CD=Cow dung, SD= Swine dung, CP=Cassava Peels, FG= Field grass.

CONCLUSION

The present study has shown that Bambara nut chaff has the potentials for biogas production though the expected increased biogas yield and extended retention time was not achieved by blending it with both animal and plant wastes. This is an indication that further work needs to be carried out to possibly treat the waste chemically to increase the pH to neutrality. This may give the expected increase in the yield of the biogas with consequent extension of the retention period. Investigation of this recommendation will constitute a separate report.

REFERENCES

[1] Edelmann, W., A. Joss and H. Engeli. Two step anaerobic digestion of organic solid wastes. In Mata Alvarez, J., A.Tilehe and J.Cecchi (Eds). 11 International symposium on anaerobic digestion of solid wastes **1999** (International Association of water quality, Barcelona, Spain) 150-153.

[2] Anunputtikul W and Rodtong S, In: The Joint International Conference on "Sustainable Energy and Environmental (SEE)", 1-3 Dec**, 2004** Hua Hin, Thailand. 238- 243.

[3] Anonymous. Waste Digester Design. University of Florida Civil Engineering, Retrieved 2003 from the World Wide Web: http:file//A:/Design.Tutor.htm.**2003**.

[4] El- Mashad, H.M. G. Zeeman, W.K.P Vanloon, A.B, Gerard and G. Lettinga *Biores. Tech.*, **2004**. 95: 191-201.

[5] Wolfe, R.S. Methane generation from human, animal and Agricultural wastes, National Academy press- Washington D.C. **1971**. pp. 1-26.

[6] Arvanitoyannis IS, Kassaveti A and Stefanatos S, *Int. J. Food Sci. Tech*. **2007,** 42 (7): 852 – 867.

[7] Bhat P.R., Chanakya H.N. and Ravindranath N.H., *J. Energy Sust. Dev*. **2001,** 1:39 – 41.

[8] Zuru A.A., Saidu H., Odum E. A. and Onuorah O.A., *Nig. J. Ren. Ener*. **1998**, 6 (1&2): 43 – 47.
[9] Bori, M.O., Adebusoye, S.A., Lawal, A.K., Awotiwon, A., *Advances in Environ. Biol*. **2007**, 1(1): 33-38.
[10] Ofoefule AU, Uzodinma EO, Onukwuli OD. *Int. J. Phy. Sci*. **2009**, 4(8): 535-539.
[11] Uzodinma, EO, Ofoefule, A.U., Eze, JI. Onwuka, ND.. *Trends Appl. Sci. Res*. **2007-a**, 2 (6): 554-558.
[12] Arvanitoyannis IS, Varzakas TH.. *Crit. Rev. Food Sci. Nut*. **2008**, 48 (3): 205-247.
[13] Kozo I, Hisajima S, and Dangh RJ, Utilization of Agricultural wastes for biogas production in Indonesia, In: Traditional technology for environmental conservation and sustainable development in the Asia Pacific region. 9th Ed., **1996,** pp. 134 - 138.
[14] Uzodinma, EO, Ofoefule, A.U., Eze, JI, Onwuka, ND. *J. Eng. and Appl. Sci*. **2007-b,** 3: 95-99.
[15] Ofoefule, A U, Uzodinma E O. *Int. J. Phy Sci*. **2009**, 4 (7): 398-402
[16] Enwere, N.J. Foods of plant Origin: Processing and utilization with recipes and technology profiles. (Afro-Orbis Publications Ltd. Nigeria) **2008**. Pp. 59-60.
[17] Ofoefule, A.U. In proc. 2nd International conference on Renewable and Alternative Energy, Federal University of Technology Owerri, Nigeria. May 16 – 19, **2010.**
[18] Ofoefule, A.U., and Uzodinma, E.O. In Proceedings of the IX World Renewable Energy Congress. University of Florence, Italy, 19-25 August. **2006,** UK: Elsevier Publishers.
[19] Ofoefule, A.U., and Uzodinma, E.O. *Nig. J. Solar Ener*. **2008**, 19: 57 – 62.
[20] Fulford D. Running a Biogas Programme. A hand book. "How Biogas Works". (Intermediate Technology Publication. 103-05 Southampton Row, London. WC 1B 4H, UK). **1998**, 33 – 34.
[21] AOAC. Official Methods of Analysis: Association of Analytical Chemists. (14th Ed., Washington, USA, 22209), 1990**.**
[22] Pearson. D. The chemical analysis of foods. (7th Edition. Churchill Livingstone. New York.) **1976,** 11-12, 14-15.
[23] Walkey, A., Black, LA. *J. Soil Sci*. **1934**, 37: 29 – 38.
[24] Onwuka, GI. Food Analysis and Instrumentation (theory and practice). (Naphtali prints. Nigeria), **2005**, 95 – 96.
[25] Renewable Technologies. Standard formula for calculating total and volatile solids. Biogas FAO, **2005.**
[26] Okore, VC, Laboratory Technique in pharmaceutics and pharmaceutical Microbiology (2nd Ed. Nigeria: El' Demark Publishers, Nigeria), **2004**, 24-26.
[27] Lapp, H.M., D.D Schulte and D.D Sparling. *Canad. Agric. Eng*. **1975**, 17: 97-102.
[28] Dennis, A., Burke, P.E. Dairy waste anaerobic digestion handbook. (Environmental Energy Company 6007 Hill street Olympia, W.A 98516). **2001**, 20p.
[29] Anonymous. A handbook of the Asian- pacific regional biogas research- training center. Operating conditions of biogas fermentation process, **1989**, 58.
[30] Garba, A., A.S. Sambo.. *Nig. J. Solar Energy*, **1992**, 3: 36-44.
[31 Energy Commission of Nigeria. Biogas: Factors affecting biogas production. In Biofuels Training Manual. **2009**, 34-37.