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Full Length Research Paper

Effect of chemical treatment and waste blending on biogas production from leaf litter of Kambala *(Chlorophoral excelsa)*

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Effect of chemical treatment and waste blending on biogas production from leaf litter of Kambala *(Chlorophoral excelsa)* was investigated. The wastes were prepared as old and untreated leaf litter (LL-OU), old and treated leaf litter (LL-OT), old leaf litter and cow dung (LL-OC) (1:1), fresh and untreated leaf litter (LL-FU) and fresh leaf litter and swine dung (LL-FS) (1:1). The treated variant was effected with the available local potash ("Ngu"50% w/v). They were subsequently charged into 50 L capacity metal prototype biodigesters in ratio of approximately 2:1 of water to waste. The moisture content of the wastes determined the water to waste ratio. They were subjected to anaerobic digestion under a 35 day retention period and mesophilic temperature range of 28 to 39°C. Results obtained showed that the fresh leaf litter variants had higher cumulative biogas yields, while the old leaf litter variants had shorter onset of gas flammability. The LL-FS and LL-FU had cumulative biogas yield of 3.134 dm^3/kg.Slurry (S) with lag period of 13 days and 3.13 dm^3/kg.S with lag period of 16 days, respectively, while the LL-OC, LL-OU and LL-OT had cumulative biogas yield of 3.04, 2.97 and 2.42 dm^3/kg.S with lag periods of 2, 2 and 3 days, respectively. General results indicate that the leaf litter of Kambala has the capability of producing biogas but not at a sufficiently high level since chemical treatment and blending with animal wastes did not translate to a significant increase in biogas production.

Key words: Leaf litter, biogas production, chemical treatment, flammable gas production, waste blend.

INTRODUCTION

Energy has always been an important aspect of man's activities. As the demand for energy is excessively increasing, there has been a relentless search for the different forms of energy that will meet up with his activities. Biogas from biomass sources is currently being recognized globally as a renewable energy source to help militate against climate change while providing a relatively cheaper source of energy for cooking and lighting for the rural/suburban populace. Being a source of renewable natural gas, it has been adopted as one of the best alternatives for fossil fuels after 1970's world energy crisis. Biogas is a colourless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane (50 to 70%), carbon dioxide (20 to 40%) and traces of other gases, such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour, etc (Edelmann et al., 1999). Biogas production is a concerted three stage biochemical process comprising hydrolysis, acidogenesis/acetogenesis and methanogenesis as follow:

1. $(C_6H_{10}O_5)n + nH_2O \rightarrow n(C_6H_{12}O_6)$ - Hydrolysis
2. $n(C_6H_{12}O_6) \rightarrow n\,CH_3COOH$ - Acetogenesis/Acidogenesis
3. $3nCH_3COOH \rightarrow n\,CH_4 + CO_2$ - Methanogenesis

Thus, for effective anaerobic digestion operation for biogas

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production, a balance among the acidogens/acetogens and methanogens is crucial (Cantrell et al., 2008). 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 (Arvanitoyannis et al., 2007). 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 on the environment (Bhat et al., 2001).

The content of biogas varies with the material being decomposed and the environmental conditions involved (Anunputtikul and Rodtong, 2004). Potentially, all organic waste materials contain adequate quantities of the nutrients essential for the growth and metabolism of the 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 age of the animal or plant (Anunputtikul and Rodtong, 2004). Many digesters have been installed in several sub-Saharan countries, utilizing a variety of wastes, such as those from abattoirs, municipal wastes, industrial wastes, animal dung and human excreta (Mshandete and Parawira, 2009). Many wastes are still being researched on as potential feedstock for biogas production.

Leaf litters abound everywhere constituting nuisance to the environment as waste and destroy the aesthetics of the surroundings. Utilizing them for biogas production would not only supply a good waste management option, but also provide a cheap source of energy. The production of biogas from leaf litters is not as common as that of animal manures and some other plant wastes like water hyacinth, field grass, peels, spent grain, etc (Uzodinma et al., 2007; Ofoefule and Uzodinma, 2008; Ofoefule et al., 2009; Ofoefule and Uzodinma, 2009), but leaf litters of apple, peach, orange and mango in co-digestion with other wastes from animals, such as swine and other plant wastes (trimmings, flowers, seeds, etc) have been utilized for biogas production (Anon, 2009a, b). Plant wastes are generally known from several reports to give low yield of biogas when subjected to anaerobic digestion alone without blending with animal wastes or pre-treating with chemicals. This has been attributed to the presence of lignin and wax in plant tissues giving rise to slower rates of hydrolysis (Lucas and Bamgboye, 1998). The acidic nature of plant wastes leading to hostile environment for the anaerobes that convert wastes to biogas has also been adduced as part of the reasons for the low yield of biogas from plant wastes. Dioha et al. (2006) reported that Neem tree leaf litter was not a good substrate for biogas production. The biogas yield was very low with short retention time of 8 days. This was attributed to the high lignin content and waxy nature of the leaves hindering microbial activity. Uzodinma et al. (2010), also reported that the leaf litters of Almond (*Prunus dulcis*), Avocado (*Persea americana*) and Kola nut (*Cola vera*) subjected to anaerobic digestion for 35 days had low biogas yield, long onset of gas flammability and short retention times. The report concluded that those leaf litters required some form of treatment/seeding/addition of inoculums to boost their biogas production. Kambala (*Chlorophoral excelsa*) is from the Iroko family. It is grown in West Africa including Nigeria, Ivory Coast and Cameroun. The wood from the tree is utilized for furniture making, boat building, flooring, canoe building, etc. The tree is located in front of the Department of Pure and Industrial Chemistry, University of Nigeria, Nsukka, Enugu state, Nigeria and poses environmental pollution especially during the dry season/harmattan due to incessant shedding of the leaves. The present study was undertaken to investigate the effect of chemical treatment and waste blending on the biogas production from the leaf litter of Kambala *(C. excelsa*). This was carried out by using both fresh and old leaf litters and subjecting them to both waste blending with cow and swine dung and chemical treatment using a cheap source of local potash ("Ngu"). The wastes were studied as old and untreated leaf litter (LL-OU), old and treated leaf litter (LL-OT), old leaf litter and cow dung (LL-OC), fresh and untreated leaf litter (LL-FU) and fresh leaf litter and swine dung (LL-FS).

MATERIALS AND METHODS

The leaf litter used for this study was collected from the surrounding of Department of Chemistry, University of Nigeria Nsukka. The cow dung was obtained from an abattoir in Nsukka market, while the swine dung was procured from the Veterinary Farm, University of Nigeria Nsukka. The local potash ("Ngu") which was used for the chemical treatment was prepared locally. Other materials used for the study include five metal prototype digesters of 50 L capacity constructed at the National Center for Energy Research and Development of the University of Nigeria Nsukka (Figure 1), and the study was carried out between October and December 2009 at the same Institute. Nsukka is located at (6.9°N, 7.4°E) and 445 m above sea level. Materials also used were; top loading balance (50 kg capacity, "five goats", model no. Z051599), plastic water bath for soaking the leaf litter, water trough, graduated transparent plastic bucket for measuring volume of gas production, thermometer (-10 to 110°C), digital pH meter (Jenway 3510), hosepipe and biogas burner fabricated locally for checking gas flammability.

Digestion studies

Preparation of wastes

The leaf litter was allowed to degrade for four months to reduce the toxicity of the waste. It was then soaked in a plastic water bath for two weeks to allow for partial decomposition of the peels by aerobic microbes which are reported to facilitate breakdown of cellulosic materials (Fulford, 1998). This was done while monitoring the pH. For the untreated and unblended wastes (LL-OU and LL-FU), 12 kg each of the wastes were weighed and mixed with 27 kg of water,

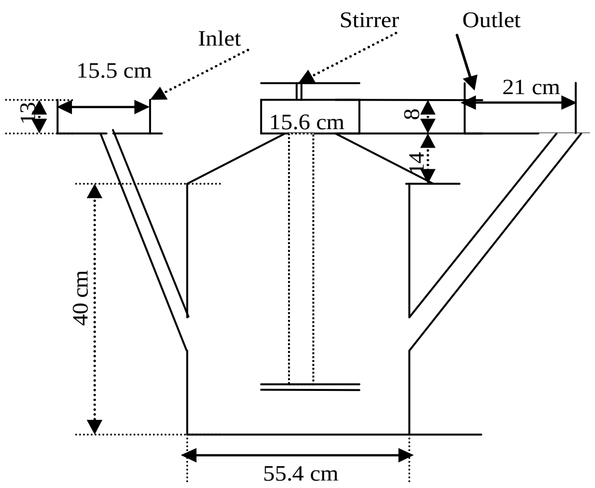

Figure 1. Schematic diagram of the biodigester.

while for the blended variants (LL-OC and LL-FS), 6 kg each of the leaf litter and 6 kg of the cow and swine dung each were mixed together giving 12 kg of total waste and then mixed with 27 kg of water. For the chemically treated variant, 12 kg of the leaf litter was weighed and also mixed with 27 kg of water. All gave water to waste ratio of approximately 2:1. The moisture content of the slurries determined the water to waste ratio. The "Ngu" obtained by the burning of empty palm fruit bunch (*Elias guinensis*) was made into solution (50% w/v) and was used for the chemical treatment. The last variant was treated with 300 ml of the solution of the "Ngu". It was left for about 6 days to ensure stability of the pH of the slurry after which the wastes were then charged into the digesters.

Charging of digesters

The wastes were charged up to ¾ of the digester leaving ¼ head space for collection of gas. The different variants were charged into the 50 L metal prototype digesters as originally weighed out. The digester contents were stirred adequately and on a daily basis to ensure homogenous dispersion of the microbes in the mixture. Gas production measured in dm^3/kg. Slurry was obtained by downward displacement of water by the gas.

Analyses of wastes

Physicochemical analyses

Ash, moisture and fibre contents were determined using AOAC (1990) method. Fat, crude nitrogen and protein contents were determined using Soxhlet extraction and micro-Kjedhal methods described in Pearson (1976) method. Carbon content was done using Walkey and Black (1934) method. Energy content was carried out using AOAC method described in Onwuka (2005), while total and volatile solids were determined using Renewable Technologies (2005).

Biochemical analyses

The pH of the wastes soaked in water and treated for a period of 6 days were monitored, while the ambient and influent temperatures were monitored daily throughout the retention period after charging of the digesters.

Microbial analysis

Total viable counts (TVC) of the microbes for the wastes slurries were carried out to determine the microbial load or the population of the microbes of the samples using the modified Miles and Misra method described in Okore (2004). This was carried out at four different periods during the digestion; at the point of charging, at the point of flammability, at the peak of production and at the end of the digestion.

Statistical analysis

The standard deviation was carried out using SPSS 15.0 version.

RESULTS AND DISCUSSION

The experiment was carried out under ambient temperature range of 28 to 34°C and slurry temperature of 34 to 39°C within a retention period of 35 days. The daily biogas production is graphically presented as shown in Figure 2. All the digester systems commenced biogas production within 24 h of charging the digester, while the onset of gas flammability took place at different lag periods (Table 2). The fresh leaf litter with swine dung (LL-FS) had the highest cumulative biogas yield followed by the fresh untreated leaf litter (LL-FU). However, their lag periods (which are from the period of charging the digester to the onset of gas flammability) were the longest (Table 2). Biogas that will serve the basic needs of cooking and lighting must be flammable. If it burns, it means the methane content is at least 45%. If it does not burn, it means the methane content is less than 45% and contains mainly CO_2 and other gases (Anonymous, 2003). The LL-FU had the longest onset of gas flammability of about three weeks. Plant wastes contain a lot of cellulose, hemicellulose, pectin, lignin and plant wax. Lignin and plant wax are very difficult to biodegrade and can be a major rate determining step in anaerobic digestion process (Ishizuka et al., 1996). This may have affected the onset of gas flammability of the LL-FU even though the gas yield was relatively high. Blending the fresh leaf litter with swine dung improved the lag period and gave the highest cumulative biogas yield. Adequate physicochemical properties are known to affect biogas production (Table 1). Blending the waste increased the carbon to nitrogen (C/N) ratio which has been given to be optimal in the range of 20 to 30:1 (Dennis and Burke, 2001). This is because the microbes that convert waste to biogas take up carbon 30 times faster than nitrogen. Blending also improved the other properties like volatile solids (VS) which are the biodegradable portion of the waste. It also improved the nutrients, e.g. fat and protein. The synergy in action between the two wastes led to the highest cumulative biogas yield of the LL-FS. The old leaf

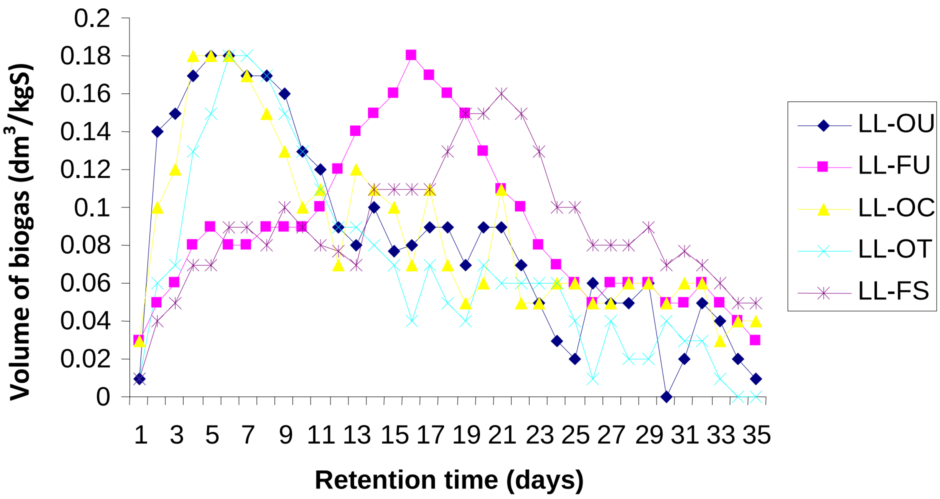

Figure 2. Daily biogas yield for the leaf litter variants.

Table 1. Physicochemical properties of the wastes.

Parameter	LL-OC	LL-OT	LL-OU	LL-FS	LL-FU
Moisture (%)	17.80	19.50	13.00	5.60	6.15
Ash (%)	14.80	18.40	12.10	10.00	4.50
Fiber (%)	25.90	31.70	27.90	4.80	12.60
Crude nitrogen (%)	2.38	2.46	2.66	2.02	2.22
Crude protein (%)	14.90	15.40	16.60	12.60	13.90
Fat content (%)	5.50	11.70	4.80	2.60	1.35
Total solids (%)	82.20	80.50	87.00	65.40	43.85
Volatile solids (%)	67.40	62.10	74.90	55.40	39.35
Carbon content (%)	50.87	56.86	56.88	40.43	39.86
C/N ratio	21.37	23.11	21.38	20.01	17.95

LL-OC = old leaf litter and cow dung, LL-OT = old and treated leaf litter, LL-OU = old and untreated leaf litter, LL-FS = fresh leaf litter and swine dung, LL-FU = fresh and untreated leaf litter.

Table 2. Lag period, cumulative and mean volume of gas production for the pure waste and blends.

Parameter	LL-OC	LL-OT	LL-OU	LL-FS	LL-FU
Lag period (days)	2 days	3 days	2 days	13 days	16 days
Cumulative gas yield (dm^3/kg.S)	3.04	2.42	2.97	3.134	3.13
Mean volume of gas production (dm^3/kg.S)	0.09 ± 0.04	0.07 ± 0.05	0.08 ± 0.05	0.09 ± 0.03	0.09 ± 0.04

LL-OC = old leaf litter and cow dung, LL-OT = old and treated leaf litter, LL-OU = old and untreated leaf litter, LL-FS = fresh leaf litter and swine dung, LL-FU = fresh and untreated leaf litter.

litter variants gave relatively lower cumulative biogas yields even though their onsets of gas flammability were faster (Table 2). This can be accounted for by the fact that they had already dried up. The lignin and wax had diminished to a very low level making it easier for the waste to be degraded faster. The LL-OU and the LL-OC gave almost the same performance in terms of cumulative biogas yield and also in the aspects of the physicochemical properties that affect biogas production like the nutrients (fats and protein), the volatile solids and the C/N ratio (Table 1). This is an indication that, at that particular state of the leaf litter, blending it with any other waste may not be necessary since blending did not have any significant effect on the performance of the waste. The LL-OT gave the least cumulative biogas yield (Table 2) with a lag period of 3 days. This also indicates that

Table 3. Total Viable Count for the Waste blends (cfu/ml).

Period	LL-OC	LL-OT	LL-OU	LL-FS	LL-FU
At the point of charging	4.6×10^6	4.6×10^7	2.23×10^7	7.0×10^6	2.31×10^7
At the point of flammability	2.0×10^7	3.23×10^7	5.10×10^7	6.06×10^7	1.09×10^7
At the peak of production	5.0×10^7	4.70×10^7	2.78×10^7	1.42×10^7	3.17×10^7
Towards the end of production	2.0×10^6	1.43×10^7	1.03×10^7	1.66×10^6	3.49×10^6

LL-OC= old leaf litter and cow dung, LL-OT= Old and treated leaf litter, LL-OU= old and untreated leaf litter, LL-FS= fresh leaf litter and swine dung, LL-FU = fresh and untreated leaf litter.

treating the old leaf litter did not have a reasonable positive effect on the biogas production even though the physicochemical properties were adequate (Table 1). This also suggests that it would be better to treat the fresh leaf litter than the old one. The result of the microbial total viable count (TVC) showed the progression of the microbes that converted the wastes to biogas (Table 3). The microbial load started at lower, increased towards the peak of gas production and reduced towards the end of the retention period which shows the death curve of the microbes.

Conclusion

The study has revealed that leaf litter is a good waste for biogas production. It can be utilized to generate energy as well as providing aesthetics for our environment. The experiment also showed that the waste from leaf litter can be utilized in three ways which are; (1) to chemically treat or (2) combine the fresh waste with animal wastes and/or (3) use the old waste as it is without any chemical treatment or blending with other waste which would translate to more cost of production. Nigeria is blessed with a lot of solar radiation, which should be tapped and used for biogas production for the rural populace by utilizing the abundant leaf litters in our environment.

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