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Biogas Production from Paper Waste and its blend with Cow dung

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ABSTRACT

A study of the biogas production potential of paper waste (PW-A) and its blend with cow dung (PW: CD) in the ratio 1:1 was investigated. The two variants were charged into 50L metal prototype biodigesters in the ratio of 3:1 of water to waste. They were subjected to anaerobic digestion under a 45 day retention period and mesophilic temperature range of 26^oC-43^oC. The physicochemical parameters of the wastes were determined including microbial analysis. Results obtained showed that PW had a cumulative gas yield of 6.23 ±0.07dm^3/kg of slurry with the flash point on the 2nd day even though gas production reduced drastically while the flammability discontinued and resumed after 14 days. Blending increased the cumulative gas yield to 9.34±0.11dm^3/kg.slurry representing more than 50% increase. The onset of gas flammability took place on the 6th day and was sustained throughout the retention period. The study showed that paper waste which abounds everywhere and is either burnt off or thrown away constituting nuisance to the environment would be a very good feedstock for biogas production. It also indicates that blending paper waste with cow dung or any other animal waste will give sustained gas flammability throughout the digestion period of the waste since animal wastes are good starters for poor biogas producing wastes. Generation of biogas from paper waste upholds the concept of waste to wealth in enhancing sustainability of development.

Keywords: Waste paper, cow dung, gas flammability, waste blend, retention time**.**

INTRODUCTION

Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions [1]. Biogas has globally remained a renewable energy source derived from plants that use solar energy during the process of photosynthesis. 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 (50-70%), carbon dioxide (20-40%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour etc. [2]. It is smokeless, hygienic and more convenient to use than other solid fuels [3]. Biogas production is a three stage biochemical process comprising hydrolysis, acidogenesis/acetogenesis and methanogenesis.

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

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 [4]. 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 [5].

The content of biogas varies with the material being decomposed and the environmental conditions involved [6]. 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 [6]. Various wastes have been utilized for biogas production and they include amongst others; animal wastes [7, 8, 9], industrial wastes [10], food processing wastes [11], plant residues [12, 13,] etc. Many other wastes are still being researched on as potential feedstock for biogas production. Paper wastes are one of such wastes being considered as a potential feed stock. Waste papers are readily available from schools, offices, printing presses, factories etc., and in some developing countries are littered on the street as waste. These already constitute a nuisance with the poor waste management system prevalent especially in the third world countries. Therefore, using it as feedstock for biogas production will be a cheaper source of energy generation as well as a good waste management option. Much work has not been done using paper waste to generate biogas; however, the only study published so far on paper waste as a biogas source is a classroom project, carried out on a laboratory scale in converting waste paper to biogas [14]. A full study was undertaken to investigate the biogas production potentials and capabilities of paper waste in terms of its cumulative biogas yield, onset of gas flammability and effective retention period [15]. The study revealed that though paper waste is a very good biogas producer, with effective retention period of 77 days, its gas flammability ceased for a period of two weeks before resumption. It was concluded that the paper waste would require some form of treatment like co-digesting it with animal wastes to impart sustained gas flammability. Cellulosic wastes are generally known to be poor biogas producers because of their poor biodegradability [16]. One treatment method for improving the biogas production of various feedstocks is co-digesting them with animal and/or plant wastes [17&18].

Consequently, this study was undertaken to investigate the effect on these stated parameters of paper waste for biogas production, by blending it with cow dung (PW: CD) in the ratio 1:1 while the paper waste alone (PW-A) formed the control.

MATERIALS AND METHODS

The waste paper used for this study was collected from a printing press in the University of Nigeria Nsukka while the cow dung was obtained from an abattoir in Nsukka market. The two digesters used are of metal prototype (50L capacity) constructed at the National Center for Energy Research and Development, University of Nigeria, Nsukka (Fig. 1). The study was carried out between January and February 2010 at the same Research Institute. Nsukka is located at (6.9^{o}N, 7.4^{o}E) and 445m above sea level. Other materials used are; Top loading balance (50kg capacity, "Five goats", model no Z051599), plastic water bath for soaking the paper waste, water trough, graduated transparent plastic bucket for measuring volume of gas production, thermometer (-10 to 110^{o}C), digital pH meter (JENWAY 3510 digital pH meter (Designed and manufactured in the EU by Barloworld Scientific Ltd, Dun mow, Essex CM63LB), hosepipe and biogas burner fabricated locally for checking gas flammability.

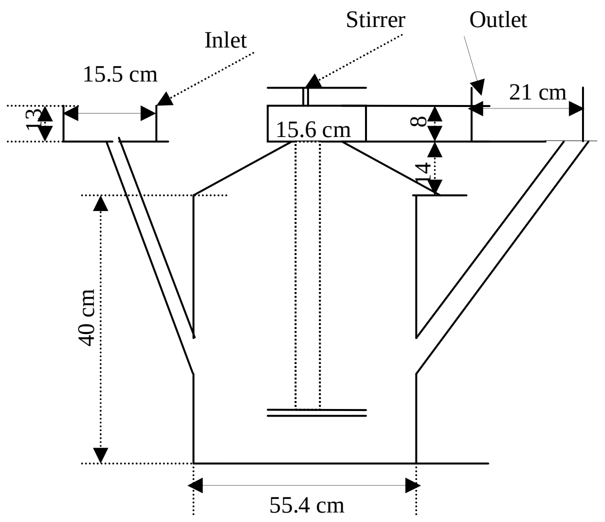

Fig. 1: Schematic diagram of the biodigester

Digestion Studies

Preparation of Wastes

The paper waste (PW) was soaked in a plastic water bath overnight to allow for partial decomposition by aerobic microbes [19], and the pH was noted. For the PW-A, 8kg of the paper waste was mixed with 27kg of water, while for the PW: CD, 4kg each of paper waste and cow dung were blended and mixed with 27kg of water, bringing all of them to water to waste ratio of approx. 3:1. The moisture content of the wastes determined the water to waste ratio.

Charging of Digesters

The two variants were charged into the 50L metal prototype digesters as originally weighed out. The wastes were charged up to ¾ of the digester leaving ¼ head space for collection of gas. The digester contents were stirred adequately and on a daily basis to ensure homogenous dispersion of the constituents of the mixture. Gas production measured in dm^3/kg of slurry (35kg) was obtained by downward displacement of water by the gas.

Analyses of Wastes

Physicochemical analyses

Ash, moisture and fiber contents were determined using AOAC (1990) method [20]. Fat, crude nitrogen and protein contents were determined using Soxhlet extraction and micro-Kjedhal methods described in Pearson (1976) method [21]. Carbon content was carried out using Walkey and Black (1934) method [22], Energy content was carried out using the AOAC method described by Onwuka [23] while Total and Volatile solids were determined using Renewable Technologies (2005) method [24].

Biochemical analysis

The pH of the paper soaked in water was taken before charging of the waste while the ambient and influent temperatures of all the wastes were monitored daily throughout the retention period.

Microbial analysis

Total viable counts (TVC) for the wastes slurries were carried out to determine the microbial load of the samples using the modified Miles and Misra method described by Okore [25]. 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 retention period.

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 26 to 36^{o}C and influent temperature range of 32 to 42^{o}C within a retention period of 45 days. The daily biogas production is graphically presented in Fig 2. The two digester systems commenced biogas production within 24hr of charging the digesters (Fig 2).

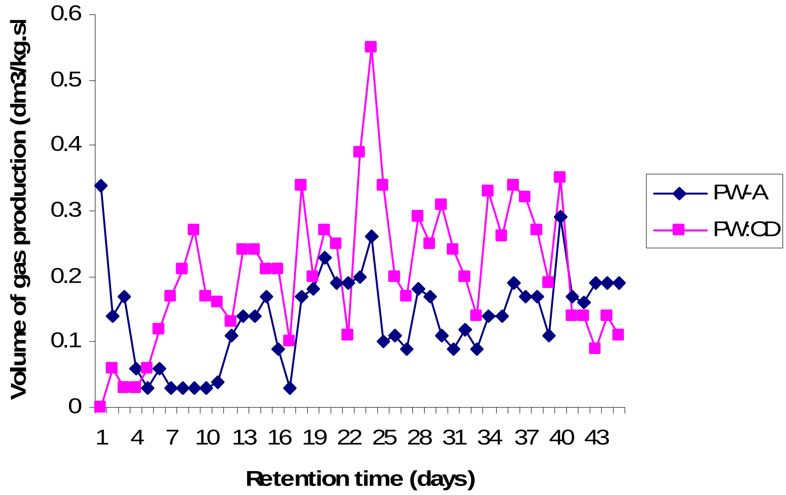

Fig. 2: Daily biogas production

The onset of flammability also took place at different lag periods (which is from the time of charging the digester to the onset of gas flammability). The paper waste alone system (PW) became flammable within 24hr of charging the digester, even though gas production reduced drastically and flammability also discontinued only to resume after 14 days. The cumulative biogas yield of the paper waste was lower than that of the blended system (Table 2). Waste containing cellulose, hemicellulose, pectin, lignin and plant wax are very difficult to biodegrade and their hydrolysis can be the rate determining step in the anaerobic digestion process [16]. The initial combustion of the gas may have been as a result of the initial microbes in the charged digester. When hydrolysis and acidogenesis commenced, there may have been a higher release of free fatty acids making the environment hostile to the microbes that convert wastes to biogas which are known to be very sensitive to pH and survive optimally at pH range of 6.5 to 8.0 [26]. This may have brought about the sudden drop in biogas production. However when the flammable biogas production resumed, it was observed that the gas production was quite high and continued long after the blend had nearly stopped production. The physicochemical properties of the waste showed that it had less favourable properties that affect biogas production like the volatile solids (which is the biodegradable portion of the waste), nutrients (crude fat and protein), Energy content and carbon to nitrogen (C/N) ratio (Table 1). Adequate physicochemical properties are known to affect biogas production. The volatile solids (VS) should be high enough to effect reasonable biogas production. The C/N ratio has been given to be optimum in the range of 20-30:1 [27]. This is because the microbes that convert waste to biogas take up carbon 30 times faster than nitrogen [28]. The C/N ratio of the paper waste was much higher than the optimum range required for effective biogas production and may have also affected the yield. The paper waste and cow dung (PW: CD) became flammable on the 6^{th} day and the flammability was sustained throughout the retention period. Blending the paper waste with cow dung brought about the sustained onset of gas flammability with higher cumulative biogas yield during the chosen retention period. This is also because blending the waste with cow dung favourably enhanced the physicochemical properties of the wastes (Table 1) as well as the microbial load of the blend especially at point of charging and peak of production (Table 3).

Table 1: Physicochemical properties of the wastes

Parameter	PW-A	PW:CD
Moisture (%)	2.85	6.20
Ash (%)	17.55	21.30
Crude Fat (%)	Trace	0.80
Crude Fibre (%)	70.80	53.40
Crude protein (%)	1.38	8.92
Crude nitrogen (%)	0.22	1.43
Carbon content (%)	10.77	32.74
Total solids (%)	97.15	93.80
Volatile solids (%)	62.60	72.50
Energy (Kcal/g)	2.74	3.97
C/N ratio	48.95	22.89
pH at charging	8.50	7.50

PW-A = paper waste alone, CW = Cow dung. Paper waste was combined with Cow dung in the ratio PW: CD (1:1)

Table 2: Lag period, cumulative and mean volume of gas production for the wastes

Parameter	PW-A	PW:CD
Lag period (days)	<24 hrs	5 days
Cumulative gas yield (dm^3/ kg. slurry)	6.23	9.34
Mean volume of gas production (dm^3/kg.slurry)	0.14±0.07	2.10±0.11

PW-A = paper waste alone, CW = Cow dung. Paper waste was combined with Cow dung in the ratio PW: CD (1:1)

Table 3: Total Viable Count (TVC) for the Pure and Waste blend (cfu/mL)

Period	PW-A	PW:CD
At the point of charging	$1.12x10^6$	$8.75x10^7$
At the point of flammability	$6.17x10^7$	$5.62x10^7$
At the peak of production	$3.03x10^7$	$8.88x10^7$
Towards the end of production	$2.37x10^7$	$4.58x10^5$

PW-A = paper waste alone, CW = Cow dung. Paper waste was combined with Cow dung in the ratio PW: CD (1:1).

Cow dung, coming from a rumen animal is known to contain the native microbial flora that aids in faster biogas production. It has also been reported severally that cow dung is a very good starter for poor producing feedstocks [29, 30&31]. The Energy content of the waste was increased as well as the volatile solids and the nutrients (crude fat and protein). The C/N ratio was also reduced to the optimum range. This is as a result of the synergy in operation between the two wastes. The cumulative biogas yield of the blend under a retention period of 45 days was still higher than the cumulative biogas yield of the single waste under a 77 days retention period which was 8.8dm^3/kg of slurry [15]. Blending or co-digestion of wastes is one of the optimization techniques known to improve biogas production [32 & 33]. All these factors may have been responsible for the better performance of the PW: CD. The result of the microbial total viable count (TVC) revealed the progression of the microbes that converted the wastes to biogas (Table 3). The microbial load started lower, increased towards the peak of production and reduced towards the end of the retention period. For the PW alone, peak of production and towards the end of the retention period had very close TVC's because at that period, the peak of gas production lingered since the paper waste continued biogas production long after the combined system had stopped. This indicates that the paper waste is a very good feedstock for biogas production since its retention period is long.

CONCLUSION

The study has shown that paper waste which abound everywhere including the immediate environment is a very good feedstock for biogas production. This waste can be utilized for energy generation instead of burning them up or having them littered around and invariably constituting a nuisance to the environment. The study has also shown that blending the paper waste with cow dung or any other animal waste will give sustained gas flammability throughout the digestion period of the waste since animal wastes are good starters for poor producing wastes.

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