COMPARISON OF THE POTENTIALS OF COW DUNG AND POULTRY DROPPINGS AS SUBSTRATES FOR BIOGAS PRODUCTION

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Abstract

Biogas is a mixture of gases (approximately 65% methane and other gases) produced by methanogenic bacteria while acting upon biodegradable materials in an enclosed chamber. With the insecurity challenges facing crude oil and gas pipelines installations, which makes source of fossil fuel unreliable in terms of availability and affordability, the need for an alternative renewable energy that is environmentally friendly, and cost saving becomes necessary for laboratory and domestic use. The comparative study of biogas production in a small-scale renewable energy plant using feedstock from cow dung and poultry droppings was carried out in the Department of Science Laboratory Technology, Nuhu Bamalli Polytechnic, Zaria. The floating top/tank digester method was used for the biogas production, using cow dung and poultry droppings as feedstock raw materials. The biogas yield for each feedstock was recorded and the respective quality parameters determined. The produced biogas was further scrubbed to purify it using available laboratory chemicals and the combustibility quality parameters determined. The results obtained reveals that comparatively, cow dung feed stock had higher cumulative yield (1262L in 20 days) of biogas than poultry droppings which has a cumulative yield of 996L in 20 days' experimental period. The research further demonstrate that biogas obtained from cow dung or poultry dropping can be purified to enhance the methane content from 61% and 64% to 79% and 81% for cow dung and poultry droppings biogas respectively. This implies improvement in the combustibility parameter of the biogas for practical heating applications. All these put together, the research has demonstrated that harnessing biogas technology utilizing cheap, locally available agricultural wastes as feedstock will contribute towards clean and reliable energy provision particularly for heating purpose. It is therefore recommended that the technology of biogas production should be encouraged and adopted in farms, rural homesteads, schools, institutions and research centres for provision of affordable renewable energy.

INTRODUCTION

Biogas is a mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and low amount of other gases. Biogas is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas (Brown, 2004). Its calorific value is 20 Mega Joules (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove. Biogas, also known as 'Green energy', once generated and stored, biogas is primarily used around the world for cooking and heating at the home scale, but it also has many other important applications both domestically and industrially. Its use as a fuel to power electric generators at all scales is well established and it also has a long history of use in gas lamps and absorption refrigeration systems. When purified and compressed it used as an effective fuel for cars, trucks and buses.. Thus biogas is a flexible substitute for non-renewable energy sources at many levels.

Energy source from fossils fuel has been available in Nigeria, however, with recent security challenges and economic sabotage to the oil installations in the oil producing areas, which threatens the availability and affordability of liquefied natural gas which is used both as cooking gas and also as laboratory/industrial gas for heating; the source of energy is uncertain. Therefore, the need for alternative, environmentally friendly source of energy has become necessary. Animal waste (e.g. cow dung) from animal husbandry, will serve as good source of biomass for renewable energy to replace and /or complement our laboratory and domestic source of energy. Most energy sources used for laboratory purposes are centred on the fossil fuel, either the liquefied gas or kerosene whose source is insecure and unreliable. Biogas from a small scale plant will provide an alternative source of energy from available and affordable waste sources.

The aim of the study is to comparatively study the feasibility of biogas production from cow dung and poultry droppings as a heating fuel in the laboratory. The study is anchored on the following specific objectives:

- To collect and utilize cow dung and poultry droppings as raw material (biomass) for biogas production in a small scale biogas plant.
- To collect data for comparative study on suitability of the biomass feed stocks, biogas yield and quality.

- To attempt the purification of produced biogas for combustibility quality enhancement.

METHODOLOGY

Sample collection

Cow dung and poultry droppings were obtained from a nearby farm in Zaria town. Approximately about 1000kg of each was collected and safely transported to the research location where it is housed under shade constructed with timber wood and zinc coated steel roofing sheets.

Determination of Proximate Composition of the Feedstock Samples.

Proximate analysis of the cow dung and poultry droppings samples were carried out by determination moisture content, dry organic matter, carbon, nitrogen, ash content as well as pH value of the samples by standard method as described by Uzodinma et al., (2008).

Biogas Plant Site and Size

A small scale biogas production plant was set up at the East wing of the School of Applied Sciences (SAS), Nuhu Bamalli Polytechnic, Main Campus, Zaria. The land area, was fenced, to cover half hectare of land, to accommodate the biogas plant and accessories and vegetable garden model farm for application/testing of the bio-manure. The biogas plant site was within a reasonable proximity to the laboratories of Department of Science Laboratory Technology, for utilization of the biogas. The criteria's for selecting an ideal plant site was that the ground (earth) was hard and compact, not water logged and damp, dry and away from shade hence have maximum day sunlight hours. The length of gas delivery pipeline was made as short as possible for effective gas delivery. There was enough protected space for slurry storage and water line and animal waste were safely stored under a shed within the site.

The biogas plant size was set up with 300 liters digester capacity, for cattle dung and poultry droppings feedstock, and an allowance for 200 cubic meter capacity for biogas storage. The volume of the mixture comprises of 150kg of either cow dung or poultry dropping mixed with 150 liters of water until and slurry is formed ready for feeding into the digester.

Preparation of Digester (Floating top/tank digester method)

The floating top/tank design digester is one that adapts itself particularly well to the materials at hand. In this design, the slurry is contained in a bottom tank, with another inverted tank or drum serving as a cap, which is lifted by the biogas as it is

generated. The design can be adapted to use any size of tanks, with a larger diameter for the outer and smaller diameter for the inner tank, and can be an excellent and inexpensive design to experiment with (Culhane 2012). The digester produced for this study consisted of a cylindrical 300-liter tank, open on top, in which the organic material is digested. A second, slightly smaller tank is placed in the larger tank, upside-down.The inner tank acts as both storage, and as a lid for the digester tank. As biogas is removed for use, the inner gas storage tank sinks back into the larger, outer tank. The gap between the tank walls is narrow enough to prevent significant quantities of oxygen from entering the digester, which would kill the anaerobic bacteria that produce the methane. The amount of biogas lost though the gap is negligible (Diver, 2002).

Experimental Set -Up

The biogas digester was started by preparing a 1:1 mixture of fresh animal manure and water, and allowing this to ferment anaerobically for several weeks. Production of biogas is signalled by the rise of the inner tank due to the biogas pressure which can be tested by ignition from the jet of the outlet tank.

The slurry used was prepared by mixing 150kg of either samples (cow dung or poultry droppings) with 150 liters of water. To each digester, 30kg of water hyacinth was added and an appropriate volume was added until the desired 300 liters slurry volume was obtained. Each digester was thoroughly stirred by mechanical shaking, to ensure the formation of homogenous mixture. The temperature and pressure of the bio-digester were determined and controlled by the aid of thermometer and an anemometer while determination of biogas yield is done by taking reading of the pressure gauge fitted on the floating tanks. The pressure of the gas was increased locally by applying carefully controlled weight on top of the inner tank. The volume of biogas yield was determined as equivalent of the volume of biogas as calculated from the determined pressure of the tank.

Purification of Biogas

For the purification of biogas a set of four plastic PET bottles (used for storing processed potable drinking water) were improvised with necessary pipe fittings and were used in this experimental work. The various plastics bottles were loaded with iron fillings, 40% sodium hydroxide (NaOH), 40% calcium hydroxide ($Ca(OH)_2$) and silica gel respectively.

Raw biogas first enters from bottom of the first bottle chamber containing iron feelings (chips available from lathe operations) and comes out from top. This will remove hydrogen sulphide and some moisture. In second chamber solution of NaOH with water is prepared with concentration of 40 %, due to exothermic reaction very high amount of heat is produced. The biogas enters from top of the chamber containing solution of NaOH. Gas is allowed to bubble in that solution and certain amount of hydrogen and carbon dioxide will get removed. In third chamber solution of Ca(OH)2 with water is prepared with concentration of 40 %. Now biogas enters from top of the chamber containing solution of Ca(OH)2. Gas is allowed to bubble in that solution and certain amount of carbon dioxide will get removed. In fourth chamber blue silica gel is kept. Biogas will enter from bottom and will come out from top of the chamber. This will remove any moisture from biogas. Composition of biogas before treatment and after purification was analyzed with aid of biogas analyser and its combustibility determined using burner.

Data and statistical analysis

Data was collected on the physical parameters set up for both cow dung and poultry dropping digesters, which includes: temperature, pH of the digester, volume of gas produced by each biomass (feedstock), weighing of raw material/feedstock, volume of liquid manure collected, and period of operation of the digesters.

Descriptive statistics were used to express the data collected. One way ANOVA was carried out to determine the level of significant difference (at 5% level of confidence) between two parameters under comparison.

RESULTS AND DISCUSSIONS

Proximate Composition of the Feedstock Samples

Table 1 shows the proximate composition of samples of feedstock used for the study. The results reveal that cow dung had a higher moisture, organic matter as well as carbon-nitrogen ratio than poultry droppings. However, poultry droppings had higher ash content and pH value than the cow dung feedstock sample. The carbon contents of both samples are in similar ranges, but for nitrogen content, the poultry droppings had a higher value in comparison with the cow dung.

Table 1: Proximate composition of samples of cow dung and poultry droppings used for production of biogas in the study.

Parameter	**Feed-stock Samples**	
	Cow Dung	**Poultry Droppings**
Total Moisture (%)	13.00	8.00
Ash (%)	22.00	30.00
Total Dry Organic Matter (%)	65.00	62.00
- Carbon (%)	38.00	36.56
- Nitrogen (%)	1.10	2.05
Carbon/Nitrogen Ratio	34.54	17.83
pH value	6.51	7.65

The suitability of feedstock for biogas production is related to their physicochemical properties which is dependent on their proximate chemical compositions. The obtained results from the study shows variation in the proximate compositions of the cow dung and poultry droppings feedstock (Table 1). While the total organic dry matter of the two feedstock are similar (65 and 62%), the poultry droppings have a higher ash content (30%) but a lower moisture content (8%) and also lower carbon to nitrogen ratio (17.83) when compared with the cow dung feedstock that has 22% ash content, 13% moisture and 34.53 carbon-nitrogen ratio. This could be related to high nitrogen content of the poultry droppings (2.05%) in relation to the cow dung (1.10%). The production of biogas is a multistep process involving degradation of the substrates by various microorganisms under the influence physical conditions within an anaerobic environment. The three well defined stages include hydrolysis of feedstock, acidogenosis and methanogenesis. The initial hydrolytic step is of paramount significance to the success and yield of the biogas plant, since the propagation of the subsequent steps depends largely on it. While the total organic matter content of the feedstock (which is to be hydrolyzed) has direct effect on the biogas yield, the carbon-nitrogen ratio of the total organic matter is the physicochemical indicator that describes the level at which hydrolysis and degradation of the organic matter prevails. Therefore, in this context, the higher carbon-nitrogen ratio as well as higher moisture content of the cow dung envisages a higher level of hydrolysis and by extension possibility of higher biogas yields.

Biogas Yield

Figures 1 and 2 shows the respective daily biogas yield and the cumulative biogas yield from digestion of cow dung and poultry droppings over a twenty-day study period. Comparatively the cow dung yielded considerably higher volumes of biogas than the poultry droppings. The cow dung had a daily yield peak of about 79 L while the poultry dropping highest daily yield is 64 L. Similarly, for the cumulative yields, cow dung yielded 1262 L while poultry droppings yield was 996 L over a twenty-day experimental period.

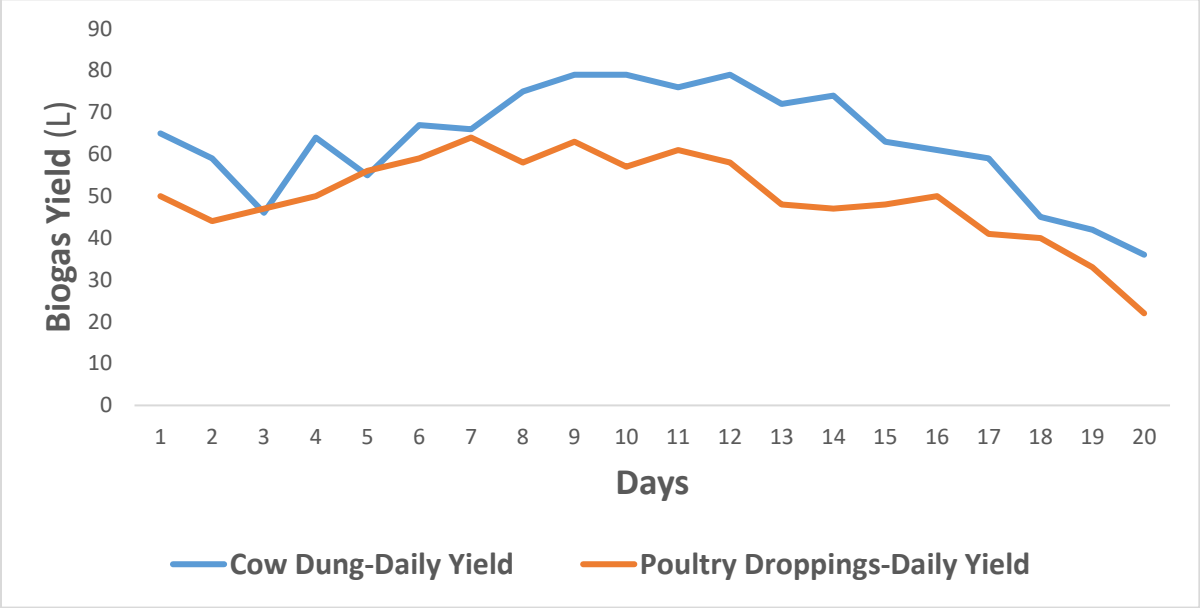

Figure 1: Daily biogas yield of cow dung and poultry droppings in a biogas digester over 20days study period.

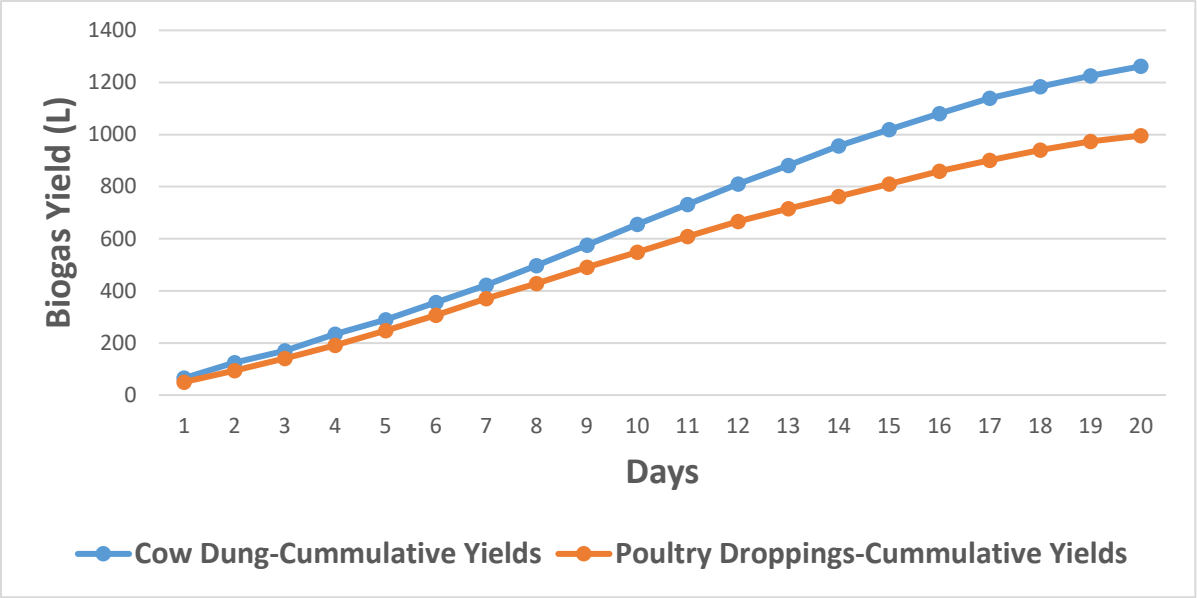

Figure 2: Cumulative biogas yield of cow dung and poultry droppings in a digester over 20days study period.

Figures 1 and 2 shows the daily and cumulative biogas yields from digestion of cow dung and poultry dropping over a twenty-day experimental period. From figure 1, it can be see that biogas yield for cow dung starts at 65L/day while poultry dropping yields began at 50L/days. These values subsequently rose to their highest yield peak of 79l/day and 65L/day before dropping to all all-time low of 36L and 22L for cow dung and poultry droppings respectively. Furthermore, it can been see from the graph the point of initial downward infliction where yields for cow dung and poultry droppings dropped to 47L and 44L at day 3 and day 2. This stage represents the initial hydrolysis stage for the feed stocks. During this stage, the digesters are engaged in enzymatic hydrolytic activities which take prevalence, after which the acidogenesis and methanogenesis stages follow that were responsible for the biogas yields represented by the upward infliction up to the peak yield rate. These peak yields were recorded at day 12 and days 9 for cow dung and poultry droppings respectively implying that the cow dung shows a higher shelf life from biogas production that poultry droppings.

The results from the figures therefore suggests that the biogas yield from cow dung is relatively higher than that from poultry droppings. This fact is further corroborated by the commutative yields of biogas over the twenty-day study period shown in figure 2. The total commutative yields stood at 1262L and 996L for cow dung and poultry droppings respectively. This superiority of cow dung with respect to biogas yield over poultry dropping can be clearly seen illustrated from the graph in

figure 2 where he commutative yields plots are almost always higher for cow dung than for poultry droppings. These variations could be explained based on the earlier findings of cow dung characteristics of higher carbon-nitrogen ratio as well as moisture contents which are parameters that promotes biogas production. These findings are in agreement with findings of other researches who reported on the high viability of cow dung as substrate of choice for biogas production (Castrillon *et. al.* 2013 and Zhang *et. al.* 2013).

Biogas Purification

Table 3 provides insight on the quality parameters of biogas from the two feedstock before and after purification by chemical scrubbing with iron fillings, NaOH, $Ca(OH)_2$ and silica gel. The results indicated appreciable improvement in combustibility parameters of the biogas for both cow dung and poultry droppings after purification. Specifically the methane contents improves after purification of cow dung and poultry droppings biogas from 61.00% to 79.60% and 64.30% to 81.02% respectively. Similarly, the oxygen content improves from 10.01% to 11.65% and 8.0% to 10.50% for cow dung and poultry droppings biogas respectively. On the other hand carbondioxide and moisture contents dropped after purification by scrubbing from 2.15% to 6.50% (cow dung); 19.16% to 5.30% (poultry droppings) and 7.84% to 2.25% (cow dung) ; 8.50% to 3.18% (poultry droppings) respectively.

Table 3: Combustibility quality parameters of biogas produced from digestion of cow dung or poultry droppings before and after purification by chemical scrubbing agents.

0	**Biogas from Cow Dung**		**Biogas from Poultry Droppings**	
Parameter	**Raw**	**Purified**	**Raw**	**Purified**
Total Yield (%)	84.10^{c}	66.15^{b}	66.40^{b}	55.60^{a}
Methane (%)	61.00^{a}	79.60^{b}	64.30^{a}	81.02^{b}
Carbondioxide (%)	21.15^{b}	6.50^{a}	19.16^{b}	5.30^{a}
Oxygen (%)	10.01^{a}	11.65^{a}	8.04^{a}	10.50^{a}
Moisture (%)	7.84^{b}	2.25^{a}	8.50^{b}	3.18^{a}

Values with different letter superscript across the rows are statistically different ($p>0.05$)

Amongst the challenges of biogas production is the fact that the biogas usually obtained had contaminants usually carbon-dioxide and water which hamper its combustibility. This research made an attempt to purify the resulting biogas using commonly available chemicals. The biogas scrubbing system consists of four units, the hydrogen sulfide (H_2S) removing unit, carbon dioxide (CO_2) removing unit, and moisture trapping unit. The four units are interconnected with plastic hoses. In the

purification process of biogas which was conducted; steel wool, and an adsorbent material (silica gel) were used. The steel wool is to react with the hydrogen sulphide, the NaOH and $Ca(OH)_2$ is to reduce the percentage of carbon dioxide while the silica gel is to reduce the presence of water vapour in the purified biogas. The experiment was done by taking the raw biogas with pressure builds up in the digester head and forced through the steel wool on its way to the biogas scrubber unit to remove hydrogen sulphide. After the hydrogen sulphide was removed by the steel wool, the raw biogas passes into the other scrubbing unit for further purification. The results obtained after the purifications shows an appreciable improvement in the combustibility parameters of the biogas. Comparatively, the methane level (which is the active fuel in biogas) improved from about 61% (raw) to 79% (purified) and 64% (raw) to 81 % (purified) for cow dung and poultry droppings respectively. Whereas the carbon dioxide levels significantly dropped from about 21% to 6% and 19% to 5% for cow dung and poultry droppings respectively. Similarly, the moisture level decreased from about 7% to 2% and 8% to 3% respectively. Combined together, this presents a significant improvement in the combustibility potentials of the purified biogas when compared to the raw biogas suggesting that this simple procedure can be used for purification of biogas towards production of high quality combustible fuel.

CONCLUSION AND RECOMMENDATIONS

The results obtained from the above study had demonstrated the feasibility of production biogas from existing agricultural wastes (cow dung and poultry droppings) in our community. The results further reveals that comparatively cow dung feed stock had higher potential for production of biogas than its related counterpart poultry droppings. The study also demonstrate that biogas obtained from cow dung or poultry dropping can be purified to enhance the methane content and other parameters, thereby improving the combustibility of the biogas in practical heating applications. The research has demonstrated that harnessing the biogas technology utilizing cheap locally available feedstock will contribute towards clean and cheap energy provision for heating purposes.

The following recommendations are hereby suggested

- The technology of biogas production should be promoted among farmers, animal homestead owners as alternative source of cheap energy.
- Institutions such as Schools, Universities and Polytechnics

should embrace the biogas production technology as system for provision of reliable and affordable source of heating fuel for laboratories, workshops etc.

- More research should be carried out to identify other potential feedstock for biogas production as well as procedures to enhance yield and quality.

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