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EVALUATION OF YIELD AND QUALITY OF BIOGAS PRODUCED FROM COW AND PIG DUNGS

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Abstract
Biogas yield and quality from cow and pig dung were evaluated. Two metal drums of capacity 200lt were used as biodigesters for the study. Slurry samples of mixture ratios of 1:1(80kg of cow dung to 80lt of water) and 1:2(40kg of pig dung to 80lt of water) for the cow-dung biodigester and the pig-dung biodigester, respectively. The biodigesters were maintained within the mesophillic temperature range (25-40^{o}c), at a retention period of 10days. The digesters were painted black to enhance effective surface absorption of solar radiation during the day, with occasional shaking of the digesters to prevent the formation of scum. Biogas yields from pig dung were higher, with a mean daily yield of 0.03m^3 than those from cow dung, which had a mean daily yield of 0.02m3. Combustibility and flame characteristics of biogas samples produced from the two biomass sources were monitored. Gas samples from the pig dung ignited readily with characteristic clear blue and stable flames. Gas samples from cow dung were readily ignited, but the flames exhibited dull blue characteristic. Clear blue and stable flames indicated biogas with high methane content (> 50%) and high thermal energy content. Pig dung therefore was proven to be a better alternative source for rural household energy needs, where poultry waste and other methane-rich biogas yielding biomass are lacking. The use of water cylinders with inverted floating cylinders as gas holder helped to clean the biogas produced by removing carbon dioxide, water vapour, hydrogen sulphide and other incombustible gaseous compounds.
Keywords*:* Biogas; Yield and combustion; Cow dung; Pig dung; Evaluation

Introduction
The dawn of industrial development brought with it a high demand for energy to sustain the fast pace of development that resulted from the accelerated scientific activities. This let to research into ways of exploiting alternative energy sources such as solar power, heat pumps, straw-burning boilers, biogas from manure digestion, wind power, water power, etc. These techniques are more likely to be cost effective when the amount of energy needed is consistent throughout the year. Considering their financial viability and environmental friendliness, biogas from organic wastes is the most appropriate. Its application in rural areas of developing countries can positively impact on the standard of living and reduce deforestation which results from excessive use of wood fuel (Lortyer *et al., 2012*).

Biogas refers to the gas produced by the biological breakdown of organic matter in the absence of oxygen. It can be produced from locally available raw materials and recycled organic wastes such as maize silage or biodegradable wastes which include sewage sludge, human and animal wastes, municipal waste, green waste, plant material, crops and food waste. The digestion process is accomplished by two types of bacteria, the acid-forming (acidogenic) bacteria which break down biomass into volatile fatty acids and acetic acid and the methanogenic bacteria which metabolize these compounds into a combination of methane-rich gas and an odourless phosphorous-nitrogen laden slurry (Obi *et al*., 2012b). These bacteria operate under three temperatures; *psychrophilic* temperature (< 25^{O}C), *mesophilic* or ambient temperature (25-40^{O}C) and *thermophilic* temperature (45-60^{O}C) (Uzodinma *et al*., 2007). Fluctuations in temperature can result in either decrease in bacterial activity or death of bacteria, which subsequently leads to decrease in biogas production (Uzodinma *et al*., 2007). Although anaerobic digestion can occur at room temperature, any method of maintaining digester temperature near the optimum temperature will increase digester performance. Thermophilc digestion is characterized by rapid fermentation, high biogas yield and short residence time. The process is used for disposal of excreta and other organic wastes because it achieves better disinfection. *Salmonela* and *Mycobacterium paratuberclosis* were reported to be inactivated within 24hours under *thermophilic* conditions which led to decrease in biogas production (Uzodinma et al., 2007). Digestion at the mesophilic range has the advantage of lower energy consumption as the decomposition of the feed stock is slower. Fermentation under this temperature range also has the additional advantage of slower death rate for specific bacteria resulting in more stability of the waste in the digester. Duran and Speece (1997) reported the death of faecal *coliform*, *Salmonella* and *Entrococcus* to be slow under the *mesophilic* conditions. Sahlstrom (2003) reported that it took months for the bacteria to be inactivated under *mesophilic* conditions. Anaerobic digestion at ambient temperature is influenced by earth temperature which is related to the atmospheric temperature and leads to decreased yield of biogas production (Dioha *et al*., 2006). The required quantity of organic waste and water mixed in the form of slurry is allowed to digest inside an air-tight tank or digester. The gas produced in the digester is collected in the dome or gasholder.The biogas comprises primarily methane (CH_4), carbon dioxide (CO_2) and traced amounts of hydrogen sulphide (H_2S) and moisture (H_2O) (Table 1). The percentage volume of each of the different compounds however depends on the type of feedstock used for the anaerobic digestion process (Richards *et al*., 1994).

Table 1: Typical composition of biogas

Constituent	Chemical formula	Percentage (%)
Methane	CH_4	50-70
Carbon dioxide	CO_2	25-45
Nitrogen	N_2	0.5-3
Carbon monoxide	CO	0-0.3
Hydrogen sulphide	H_2S	Trace
Hydrogen	H_2	1-10

Source: Obi *et al* (2012)

Normally, when human or animal manure is left to decompose naturally, two main gases which cause global warming namely nitrous dioxide (N_2O) and methane (CH_4), are released. Nitrous oxide warms the atmosphere 310 times more than carbon dioxide and methane 21 times more than carbon dioxide (Brown, 2006). The major advantages of converting manure to methane-rich biogas via anaerobic digestion is that it helps to minimize emission of global warming gases and generates enough electricity to meet up certain percentage of nation's electricity expenditure (Webber and Cuellar, 2008). Development of biogas technology in Nigeria would enable the use of wastes from millions of cows, poultry and other domestic animals to generate billions of kilowatt hours (kwh) of electricity, enough to power millions of homes across the country. In Nigeria, daily production of fresh livestock waste has been estimated at 227,500 metric tonnes (Igboro, 2011and Ahmadu *et al.*, 2009). In addition, Nwude *et al* (2010) estimated daily generation of municipal solid waste at 20 kg per capita. Going by Nigeria's 1991 population census figure of 88.5 million people, an estimate of 1.8million metric tonnes of municipal solid waste would be generated daily (Igboro, 2011). Given that 1 kg of fresh livestock waste produces about 0.03m^3 of biogas, Nigeria has the potential of generating about 6.8 million m^{3}of biogas every day from livestock waste alone (Ahmadu *et al.*, 2009; Igboro, 2011). It has been estimated that one cow can produce enough manure in one day to generate 3kwh of electricity, which only 2.4kwh of electricity is needed to power a single 100w light bulb for a day (SECOT, 2009). This quantity of gas would contribute to the country's electricity expenditure and considerably reduce the dependence on firewood and thereby reduce deforestation and desertification (Igboro, 2011).

Previous efforts on promotion of biogas technology as a better alternative source for rural household energy requirements include the work of Obi *et al* (2012), Lortyer *et al* (2012),Fasiku *et al* (2012), Igboro (2011), Abdulkareem (2011), Jolaiya *et al* (2010), Ahmadu *et al* (2009), Brown (2006) and Abubakar (2003). Survey of available literature shows that no work has been conducted to compare yield and quality of biogas produced from different animal dungs. It is against this background this study was undertaken to evaluate yields and combustibility of biogas produced from cow dung and pig dungs.

Materials and Methods

The cow and pig dungs used for the study were obtained from the livestock unit of Samaru College of Agriculture, Ahmadu Bello University, Zaria, Nigeria. The study was conducted at the Department of Agricultural and Bio-environmental Engineering Technology, Samaru College of Agriculture, ABU, Zaria, between November and December, 2011.Two empty metal-oil drums of capacity 200lt were used for the anaerobic digesters (Plates 1a and 1b) and water cylinders with inverted floating cylinders as a gas purifiers as well as a gas holding chambers. Other materials used include a 20lt calibrated-plastic bucket for measuring water, a cylindrical aluminum basin for preparing slurry, a 25kg weighing balance for weighing feed stock, a digital pH meter, a 1lt plastic funnel for feeding the slurry into the digester, plastic hand gloves and face masks for hygienic purpose.

Using the cylindrical aluminum basin, 80kg of cow dung and 40kg of pig dung were dissolved separately in 80lt of water. When the manure was allowed in water for 30 minutes, the mixture was stirred properly into a slurry form. The 200lt metal-drum digesters were fed in with slurry quantities of ratios 1:1 (80kg cow dung to 80lt water) and 1:2 (40kg swine dung to 80lt water), with slurry inputs of 0.20m^3/batch, and 0.30m^3/batch, respectively. The operating volume of slurry in each digester or batch input (Sd) was determined by use of the equations (Kossmann *et al.*, 2001), applied below:

Sd = [biomass(b) + water(w)m^3/batch……………………………………………………(1a)
= 0.1 + 0.2 = 0.3m^3/batch for the swine-dung gas plant.
Sd = [biomass(b) + water(w)]m^3/batch……………………………………………………(1b)
= 0.1 + 0.1 = 0.2m^3/batch for the cow-dung gas plant, and

For the batch type digester, the daily slurry input (batch input) is equal to the operating volume of the digester (Vo). Therefore, for the cow-dung and pig-dung digesters, the operating volumes were determined by the equations (Kossmann *et al.*, 2001), below:

Vo = Sd x Tr = 0.3m^3…………………………………………………………………(2a)
Vo = Sd x Tr = 0.2m^3…………………………………………………………………(2b)

Where,Vo = operating volume of the digester, Sd = daily slurry input in the case of batch type digester and Tr = retention or residence time.

After loading the digesters, the inlet ports were immediately closed tightly to prevent air into the digesters for effective digestion of the slurry. Delivery tubes were connected from the digesters to gas collectors through water cylinders, where the biogas was purified by dissolving excess CO_2 and other non-combustible gases in the water (Fasiku *et al*., 2012). The two biodigesters were maintained within *mesophillic* temperature range (25-40^{o}c) and time of 10days. The digesters were painted black to provide an absorptive surface for the absorption of solar radiation during the day time and were occasional shaken to prevent the formation of scum (Igboro, 2011)

***Measurement of Biogas Yield*:** Biogas produced from the fermented feedstock was measured by use of "downward delivery and upward displacement" theory (Fasiku *et* al., 2012). The gas displaced water in the water cylinder and was trapped between the gas holder and the water level. The depth of displaced water was the distance between the top edge of the water cylinder and the new level of water in the water cylinder. The volume of water displaced by 1cm was approximately 1.5lt. The average volume of gas recorded daily was taken by measuring the volume of water displaced from the water cylinder and the depth of the displaced water. The displaced water was the equivalence of the volume of biogas produced daily. The readings were taken for 9 days, twice in a day, at 12:00noon and 5:00pm, and the average recorded for the day.

***Biogas Combustion Test*:** Gas from the inverted floating cylinders of the digesters was delivered to a biogas stove via a gas line. Turning on the release valves, the gas was lighted with a match stick. Using a 5-man test panel, mainly gas welding technicians and dealers of cooking gas and cylinders, the parameters observed were ease of ignition, colour of burning flame and stability of the flame. Biogas samples that ignited easily with clear blue and stable flames indicated high methane (> 50%) and thermal energy contents; samples that ignited but exhibited dull blue and stable flames indicated biogas with average methane content (about 50%), while gas samples that did not ignite easily or ignited with smoky yellowish and unstable flames indicated low methane contents (< 50%).

Results and Discussion

The residence time for the study was ten days but gas yield measurement and recording began the second day after loading the digesters (Tables 2-3). The results show that both cow and pig dungs produced substantial quantities of biogas throughout the residence period and the gas samples all ignited readily. However, gas yields from pig dung were higher (0.03m^3) than yields from cow dung (0.02m^3). These results conform to literature reports on pig dung having superior biogas yields over biogas yields from cow dung (Fasiku et al., 2012; Abdulkareem, 2011; Kasisira and Muyiiya, 2009).

Table 2: Daily biogas yield from anaerobic digested cow dung

Residence time (day)	Displaceddep (cm)	Displaced water vol. (lt)	Displaced water vol.(m^3)
1	37.54	25.03	0.03
2	39.67	26.45	0.03
3	41.66	27.77	0.03
4	40.78	27.19	0.03
5	36.65	24.43	0.02
6	28.79	19.19	0.02
7	23.49	15.66	0.02
8	22.86	15.24	0.02
9	20.58	13.72	0.01
Average	32.45	21.63	0.02

Table 3: Daily biogas yield from anaerobic digested pig- dung

Residence time(day)	Displaceddepth (cm)	Average gas vol. (lt)	Average gas vol.(m^3)
1	47.24	31.49	0.03
2	50.67	33.78	0.03
3	58.56	39.04	0.04
4	53.78	35.85	0.04
5	46.05	30.70	0.03
6	38.71	25.81	0.03
7	33.19	22.13	0.02
8	30.36	20.24	0.02
9	28.58	19.05	0.02
Average	43.07	28.71	0.03

Gas samples from the two digesters all ignited, but the burning flames of gas samples from pig dung gas were blue and stable (Table 4). Although the gas samples from cow dung ignited and the flames were stable, the colour was dull blue. The clear-blue and stable flame characteristic of biogas from pig dung indicate high methane (CH_4) content (> 50%) as well as high-thermal energy content in the generated biogas (Abdulkareem, 2011). The dull blue flame characteristic exhibited in the burning biogas from cow dung indicates low methane content (< 50%) in the produced biogas (Igboro, 2011).

Table 4: Combustion test of biogas samples from cow and pig dung

Type of waste	Average gas vol. (lt)	Average gas vol.(m^3)	Ignition, colour and stability
Cow dung	21.63	0.02	Easy, dull blue and stable
Pig dung	28.71	0.03	Easy, clear blue and stable

The findings of this study show that biogas produced from pig dung has higher methane and thermal energy contents than biogas produced from cow dung. It is therefore a methane-rich biogas yielding biomass that could serve as a better alternative source for rural household energy needs.

Plate 1a: Biogas plants for cow dung

Plate 1b: Pig dung digestion

Conclusion

The results show the mean daily yield of biogas from pig dung to be $0.03m^3$, while the yield from cow dung was $0.02m^3$. It is therefore obvious that pig dung is a better alternative bioenergy source where poultry waste and other high methane-rich biogas yielding biomass are lacking. The use of water cylinders helped to clean the produced biogas by removing carbon dioxide, water vapour and hydrogen sulphide present in the produced biogas. Gas flames from biogas samples produced from pig dung were clear blue and stable, indicating high methane content (> 50%) and high-thermal energy content. Biogas samples from cow dung, though all ignited and were stable, the flames were dull blue, indicating that the biogas produced had low methane content (< 50%) and low thermal energy content. Flames from cow dung gas samples showed low methane content(< 50%) as well as biogas low thermal-energy content.

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