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Full Length Research Paper

Experimental study of anaerobic digestion of dog waste

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Bioconversion of dog waste (dung) to energy as one of the ways for proper disposal of the waste was carried out through anaerobic digestion for biogas production. The 59-day experiment was performed within the slurry temperature range of 28 and 44°C using a 50 L metallic biodigester. Prior to charging the digesters, physico-chemical properties and microbial content of the waste were determined using standard methods. The results show that a cumulative gas production of 200 L was generated by 7 kg of the waste at the end of the test period while the microbial load decreased from 8.2×10^{14} at the beginning of the test to 4.2×10^{8} at the end of the retention time. Five microorganisms were identified at the beginning of the charging period, four were identified at the 20th day when the gas began to burn due to methane production while only one microorganism was identified at end of the test. Even though it has longer retention period than most common animal wastes used for biogas production, its gas production rate is low. However, pathogen reduction through anaerobic digestion justifies its conversion to energy by this method.

Key words: Dog Waste, biogas, anaerobic digestion, renewable energy, biodigesters, microbial count.

INTRODUCTION

Proper waste management is an issue in developing countries. Diseases and sicknesses are associated with improper waste handling and disposal. One of the ways of preserving the environment which is being affected by global warning due to heavy consumption of fossil fuels is by use of alternative renewable energy fuels. By this, ground water contamination, diseases and sicknesses as well as air pollution are abated.

Biomass technology has become one of the sources of renewable energy fuels for the present and future energy use that will help reduce the level of environmental pollution resulting from use of fossil fuels and improper waste disposal. It is widely used as source of biomass energy for cooking, heating and electricity generation for lighting and running of internal combustion (IC**)** engines.

Biomass is accumulation of solar energy on earth in the form of plant and animal materials. Dog waste (excreta) is easily found littering the environment in developing countries due to poor handling and ignorance of its usefulness in energy production. Dog rearing is common among individuals and organizations as pet and for security purposes.

Bacteria and pathogens are associated with dog wastes (Beck, 1979) which are harmful to human health (Unruh et al., 1973). Of greatest concern here are parasitic worms, round worms, hookworms and tape worms (Prociv and Croese, 1990).

Composting is discouraged as a method of disposal of

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Figure 1. Biodigester prototype used in the experiment.

dog waste due to its pathogen content. It contains bacteria and pathogens that are harmful to humans. Like other animal manures, dog manure has high nitrogen content which increases its carbon to nitrogen ratio hence affecting the decomposition process (Taylor, 2004). Rather than allowing dog dung waste away, its energy potential is being explored. Animal waste is being screened to see how it might be reused in a bid to making the environment clean. Usually, if dog waste is not tossed out, it is left where it falls and dissolves into the ground where it flows untreated into the water table. Another common method of its disposal is by scooping into compost bin alongside the yard waste which can be regarded as poor method of disposal due to its susceptibility to human disease.

In this work it is proposed that one of the ways to get rid of the menace of dog dung is by anaerobic digestion for medium energy fuel production. Anaerobic digestion is the microbial decomposition of biomass in the absence of oxygen. The major product of this bacterial activity is the release of biogas, a combustible gas that is rich in methane and contains carbon dioxide, water and hydrogen sulphide in trace quantity. Anaerobic digestion of different animal wastes has been carried out by many scholars. Abubakar and Ismail (2012) have carried out an investigation on biogas production potential of cow dung using a laboratory scale 10 L bioreactor. It was found that cow dung stands a promising feedstock for biogas production even at a laboratory scale. Three wastes types comprising cow dung, cowpea and cassava peels have also been subjected to anaerobic digestion (AD) investigation by Ukpai and Nnabuchi (2012). In their work cowpea produced highest percentage of methane followed by cow dung while the cassava peels produced the least. On cumulative scale, cow dung produced the highest cumulative biogas yield of 124.3 L/total mass of slurry. At domestic level, 11 m^3 biodigester has been operated at National centre for Energy Research and Development, University of Nigeria Nsukka using cow dung as feedstock (Eze et al., 2011). At full capacity, the biogas generated from cow dung using this digester is capable of producing energy required for up to 6 h of household continuous cooking. In Nepal, Singh et al. (2008) have demonstrated the use of poultry waste in biogas production. It was found that poultry droppings could provide additional energy required for the farm operation if anaerobic digestion is incorporated in the management of the wastes. Biogas generation from animal wastes is not limited to domestic or farm animals. Atanu et al. (2010) carried out laboratory experiment on biogas generation from AD of elephant droppings. It was found that this waste can produce biogas containing 48 to 60% methane even though biogas generation did not start until after 12 days of fermentation.

A survey of scholarly articles show several works done on biogas generation using plant, animal and industrial wastes with little or no information on use of dog wastes for energy production. In the review of current advances in biogas production, provided by Demirel et al. (2010), dog waste is not mentioned as one of the wastes that could generate energy. Among all the animal wastes used so far for biogas production at both laboratory and field experiments, AD of dog waste is scarcely reported. This may be partly because of the quantity of the waste or partly because of its susceptibility to pathogens. Therefore it becomes important that biogas production potential of this waste be investigated with a view to advising for its proper disposal. Anaerobic digestion of animal wastes has been found to have a long time benefit. In some cases Anaerobic digestion processes have often been applied for biological stabilization of solid and liquid wastes (Demirel et al., 2010). Similarly, it has been found that the slurry (effluent) can be used in crop production as biofertilizer which has better nutrient quality than the raw waste (Okoroigwe, 2007; Okoroigwe et al., 2008). The aim of this investigation is to determine the biogas production potential of dog waste. The work will understudy the bacterial count of the digested effluent with a view to advising for its proper disposal.

MATERIALS AND METHODS

In this study, the dog waste (dung) used was collected from the dog unit of University of Nigeria, Nsukka security post and Department of Veterinary Medicine while the anaerobic digestion experiment was carried out at the National Centre for Energy Research and Development, (NCERD), University of Nigeria Nsukka. Prior to biodigestion process, proximate analysis of the waste was carried out using standard methods to determine the moisture and ash content. Physicochemical properties such as pH, temperature, crude fibre, protein, fat etc were also determined prior and during the biodigestion period. The action of microorganisms in the decomposition process of the substrate is very important to determine the progress of biogas production. Hence, the microbial load of the substrate was determined at three different periods during the biodigestion process. This was determined using the surface viable count method outlined by Okore (2004). After determination of preliminary parameters of the substrate, the AD proceeded with the charging of the 50 L biodigester (Figure 1) with

Table 1. Result of proximate analysis.

Parameter	%
Moisture	74.8
Ash	1.50
Protein	2.19
Fat	0.15
Fibre	0.55
Total solids	25.2
Volatile solids	20.5
Potassium	1.50
Calcium	0.06
Magnesium	0.32
Phosphorus (mg/100 g)	0.48
Carbon	2.98
Nitrogen	0.175
C:N ratio	17.0
Onset of flammability	20^{th} day

7 kg of dog dung mixed in 21 kg of water. The set up was made airtight to ensure anaerobic condition and kept in an open space at the biomass digestion ground of NCERD. This was to ensure that the set up was operated at the normal prevailing environmental conditions of temperature and pressure. The 59 day experiment lasted from December 2008 to January 2009.

Biogas generated was measured daily at specific time of the day to ensure 24 h gas production period. The volume of gas in liters was measured by downward displacement of water in a trough calibrated in 0.5 L scale.

The gas production rate was calculated according to the relation:

$$S_g = \frac{V_g}{R_t} \quad (1)$$

Where, S_g = gas production (Lday^{-1}); V_g= cumulative gas production (L), and R_t = retention time (days)

RESULTS AND DISCUSSION

Physico-chemical parameters

The physical and chemical parameters of the sample as determined through the analysis above are presented in Table 1.

C/N ratio

Among factors that affect biogas yield from AD of wastes are pH, Hydraulic Retention Time and C/N ratio (Oparaku et al., 2013; Yadvika et al., 2004). According to Wang et al. (2012), C/N ratio is an important indicator for controlling biological treatment systems. High C/N ratio indicates rapid nitrogen consumption by methanogens and leads to lower gas production while low C/N ratio results in ammonia accumulation and an increase in pH values, which is toxic to methanogenic bacteria (Zhang et al., 2013). Usually, during anaerobic digestion, microorganisms utilize carbon 25 to 30 times faster than nitrogen (Yadvika et al., 2004). To meet this requirement, microbes need a 20 to 30:1 ratio of C to N). The characterization result of the dog waste sample shows that it contains a CN ratio of 17. This is small compared to the recommended ratio above. This could be responsible for the low gas production within the first 20 days of digestion (Figure 2). This is also responsible for the acidic nature of the slurry during the initial days (Figure 3).

Flammability/methane content

Flammability (evidence of methane content) started at the 20^{th} day which presumes that ammonia production due to low CN ratio might be predominant at early digestion days. This delay period was also obtained by Ofoefule and Uzodimma (2009) in the blend of cassava peels waste with pig dung in anaerobic digestion process. The explanation is also based on large ammonia production from cassava peels digestion.

Effect of volatile solids and total solids (VS and TS)

The result also shows that the waste has a volatile solid concentration of 20.5% and total solid concentration of 25.2% in the dung (Table 1). This shows the amount of the dung convertible to gaseous element and providing nutrients to the microorganisms for their function. The low VS contributed, along other parameters, to the low gas yield recorded in the first 20 days since the microbes could not breakdown the substrate as easily as possible. Gas yield increased from the 25^{th} day when there was a balance between the TS consumption and VS conversion to gas. The 25.2% TS and 74.2% moisture content of the dog waste are close to 20 and 80% respectively for human excreta due to the nature of diet dogs feed on.

Biogas yield

The biogas yield profile of the substrate (Figure 2) is typical of biogas production profile from anaerobic digestion of animal wastes. The profile is characterized by fluctuation in biogas production over time due to many factors which include complex microbial activities. The processes of AD are complex chemical reactions between the microorganisms and the substrates which are affected by a number of factors as indicated above and the prevailing climatic and environmental factors. Temperature affects the reaction resulting in changes in biogas yield. The result of the daily gas yield of the dog waste is shown in Figure 2 while the cumulative biogas

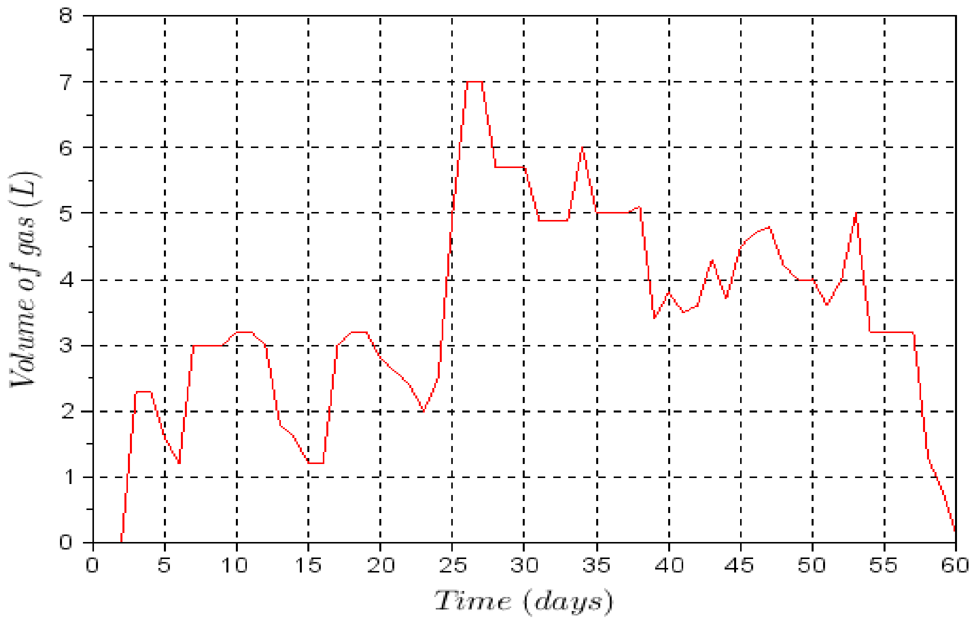

Figure 2. Daily biogas production from the dog waste.* is converted by authors from the original source.

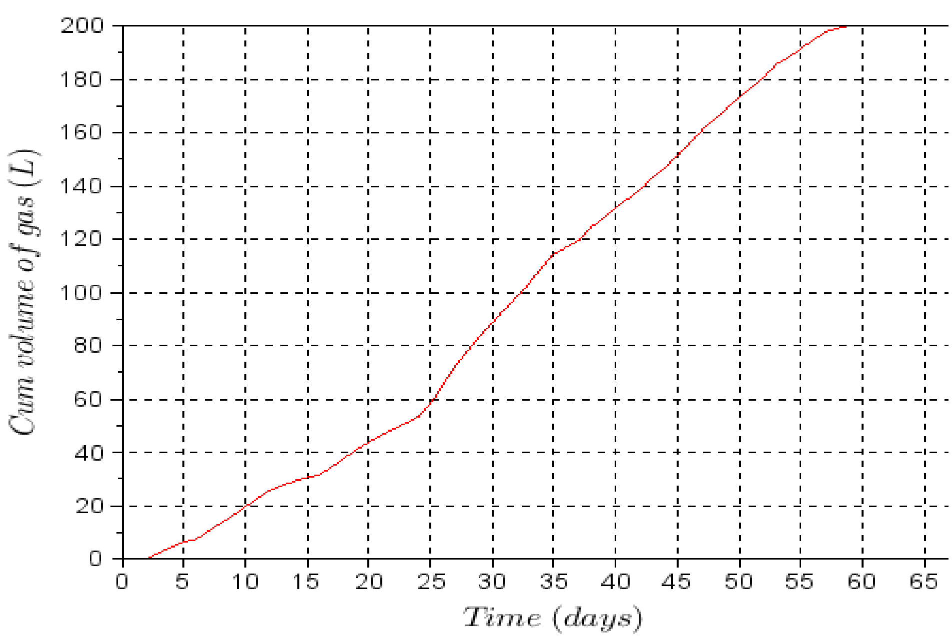

Figure 3. Cumulative biogas production of the dog waste.

production over the entire biodigestion period is shown in Figure 3. The gas production rate is calculated as 0.07 L/day using Equation (1). On unit mass of substrate, the gas production specific volume yield (SVY) is 28.57 L/kg, or 0.029 m^3/kg. This value is similar to 0.028 $^*m^3$/kg reported by Balasubramaniyam et al. (2008) for human excreta. This could be because both animal wastes type have similar physico-chemical properties. The dog's biogas SVY is less that 0.3, 0.5 and 0.5 m^3/kg reported by Ilaboya et al. (2010) for Cattle dung, Pig dung and Poultry droppings respectively. Since human waste has been used for biogas production, dog waste can be used also. An advantage of using dog dung for biogas production is on its long retention time as gas production

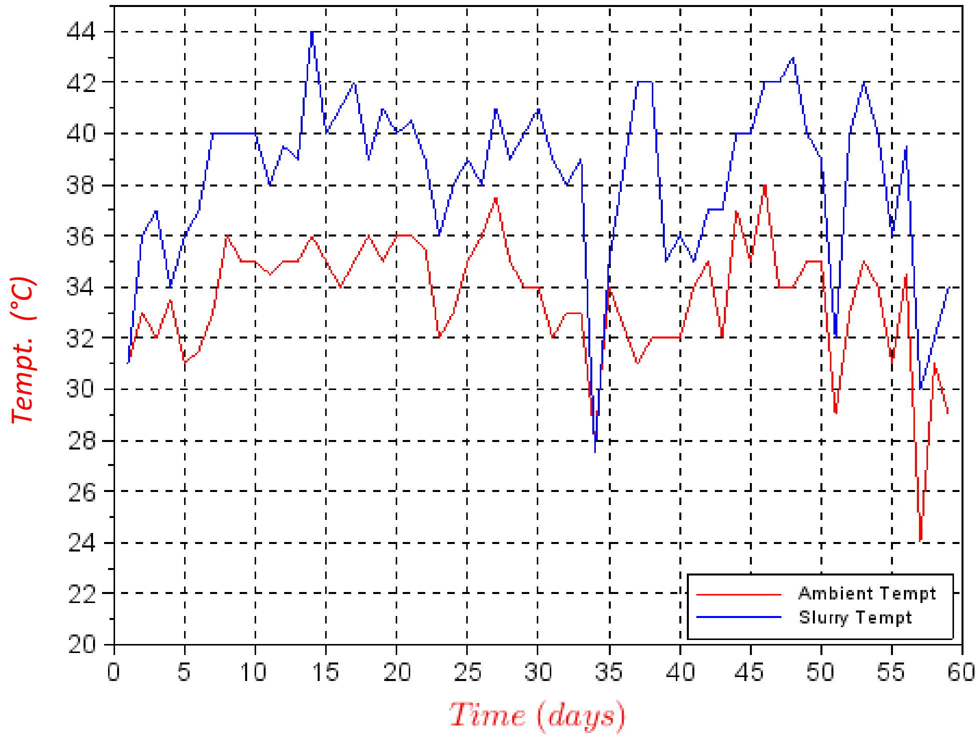

Figure 4. Temperature variation during the biodigestion period.

continued up to 59th day. The quantity of dog waste product is a limitation in using this for large biogas production.

For the 59-day testing of the wastes, a total of 200 L of gas were collected.

Temperature effect

Figure 4 shows the temperature variation during the test period. The slurry temperature was between 28 and 44°C which is the mesophillic temperature regime. There was no external influence of the slurry temperature as this was only affected by the activities of microorganisms. The external temperature (ambient) was only influenced by natural weather condition. The period was during the harmatan wind characterized by dryness and cold wind across Sahara. The highest ambient temperature was 38°C while the lowest was 24°C. This condition is favourable for biogas production during AD of animal wastes unlike adverse cold witnessed during winter in temperate climate when the temperature assumes negative values.

pH variation

The pH of the slurry ranged from 6.36 to 7.78 as shown in Figure 5. The microorganisms that are involved in biodigestion processes are usually affected by the acidity of the medium. The activities of these acitogens and methanogens result in the variation of pH of the medium and subsequently affect biogas production. Optimum biogas production is usually obtained within the pH range of 6.5 to 7.5. Maximum gas production was obtained between the 25th and the 35th day (Figure 2) when the pH was near neutral (Figure 5).

Microbial load

Table 2 presents the type and number of microorganisms in the waste at major times of the analysis. It shows that the waste had higher microorganism content at the beginning which was a combination of aerobic and anaerobic organisms. At flaming period the organisms (*Butyrivibrio* sp.) were no longer present which was responsible for the decrease in the microbial count (TVC) of the identified organisms. These were responsible for aerobic activities that utilized initial oxygen trapped in the system at commencement of fermentation. When methane began to build up C*lostridium* sp., *Ruminococcus* sp., *Acetivibrio* sp. *and Eubacterium-cellulosolvens* were predominant. It could be affirmed that methane production could be hindered as long as *Butrivibrio* sp. remains in the system. Identification of the quantity of each microorganism can explain better the role of each organism in production of flammable gas.

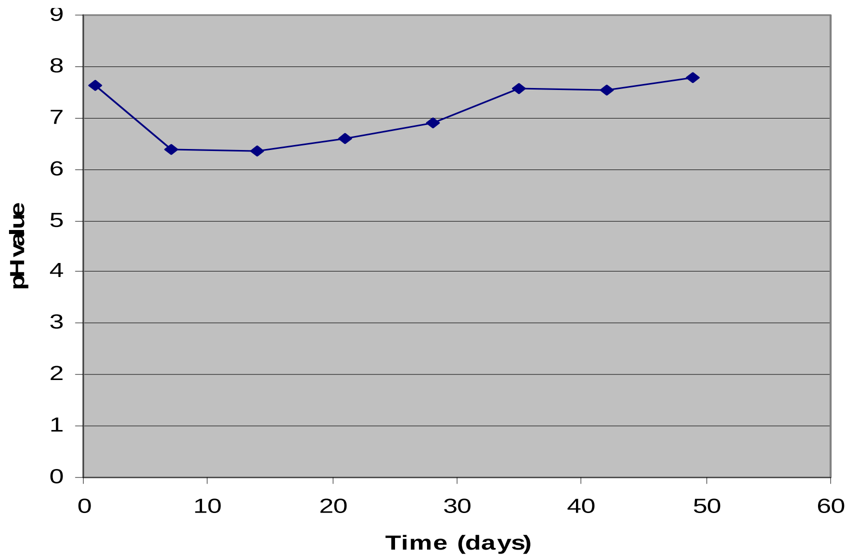

Figure 5. pH variation of the waste.

Table 2. Organisms/microbial species isolated and TVC at various stages of the anaerobic digestion of the dog feaces.

Organisms	At charging of waste	At flammability	At the end of gas production
Bacteria type	*Butyrivibrio* sp., *Clostridium* sp., *Ruminococcus* sp., *Acetivibrio* sp., *Eubacterium-Cellulosolvens.*	*Clostridium* sp., *Ruminococcus* sp., *Acetivibrio* sp., *Eubacterium- cellulosolvens*	*Clostridium* sp.
TVC	8.2×10^{14}	7.6×10^{11}	4.2×10^{8}

This further reveals the total disappearance of all the organisms at the end of the production stage leaving only the *Clostridium* sp. This conforms to the conclusion of Ofoefule et al. (2010) that AD does not completely eliminate microorganism in animal wastes. This probably implies that these bacteria were not involved in gas production or that the environment might not be conducive for their activity even though they accounted for 420 million of the identified organisms (Table 2). Decrease in microbial load over the period of biodigestion is a common phenomenon in microbial reactions. This has been observed by McGarvey et al. (2007) and Ofoefule et al. (2010).

Conclusion

Different biomass materials have different biogas generation potential. Whereas many have been tested to have high biogas viability, dog waste has low biogas production potential. From the results obtained, it can be seen that dog waste has biogas generation potentials even though the production rate is very slow and with high retention time. Although gas yield was low, it can be used as innoculum for increasing the retention time of other biomass since it has high retention time. It is not however advisable to depend on dog waste alone for biogas production mainly due to the quantity of biomass is usually small and its biogas has long time to flame. Anaerobic digestion is a better option to composting in terms of pathogen handling and control.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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