THE CATALYTIC EFFECT OF TERMITES IN THE ANAEROBIC CO-DIGESTION OF PIG MANURE AND WATER LEAF TOWARDS BIOGAS PRODUCTION

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ABSTRACT

In this study, the biogas production potential of pig manure and water leaf in the ratio of 4:1 (pig manure: waterleaf) was investigated. The two substrates were mixed thoroughly with water and charged into a metal prototype biodigester in the ratio 2:1 of water to waste. They were subjected to anaerobic digestion under a 40 day retention period and mesophilic temperature range of 24^{o}C to 28^{o}C. Enzymes extracted from termites were introduced into the feed stocks to facilitate the rate of production of biogas. The experiment was conducted within water resources laboratory of the Department of Civil and Environmental Engineering of the Federal University of Technology, Akure, Nigeria. The results obtained from the plot of the cumulative gas yield against retention period showed that there was no gas production for the first 8 days of the retention period for the termite-aided co-digestion process. An improvement in the amount of biogas produced was noticed after Day 15. The results showed that the co-digestion of pig manure with water leaf has the potential to produce biogas but the amount of biogas produced can be optimized by the introduction of enzymes obtained from the gut of termites.

Keywords: Biogas Production, Pig manure, Water leaf, Enzyme, Termites.

INTRODUCTION

About 88% of the world's energy needs rely upon fossil fuels (Weiland, 2010) as global energy needs increase rapidly. Demand for energy is expected to increase by more than 50% by 2025, as a result, there is an ongoing search to develop sustainable, affordable, environmentally friendly energy from renewable sources (Deublein and Steinhauser, 2008; Khanal, 2008). A global movement toward the generation of renewable energy is therefore under way to help meet increased energy needs.

The generation of waste in towns and cities could provide a source of fuel of renewable energy. Millions of cubic meters of methane in the form of swamp biogas are produced every year by the decomposition of organic matter, animal and vegetable waste (Re-energy, 2007). Biogas, which is described as a naturally occurring gas formed as a by-product of the breakdown of organic waste materials in an anaerobic environment, comprises mainly of methane and carbon dioxide and may have traces of hydrogen sulfide (H_2S) and fractions of water vapor. According to Kapdi *et al.* (2004), raw biogas contains about 55-65% methane (CH_4) and 30-45% carbon dioxide (CO_2).

A number of researchers have worked on biogas technology in Nigeria and Africa as a whole. Itodo *et al.* (2007) studied the Performance evaluation of a biogas stove for cooking in Nigeria. Ofoefule (2011) investigated the the biogas production potentials of Bambara nut chaff which is obtained from Bambara nut (*Vigna subterranea*) which is grown in the Northern part of Nigeria and other parts of West Africa largely consumed in the north eastern part of Nigeria. Ilaboya *et al.* (2010) studied Biogas Generation from Agricultural Waste. Rabah *et al.* (2010) investigated the biogas production potential of abattoir waste at different retention times. Abbey (2005) studied the development of biogas technology in Uganda and concluded that it has the potential to reduce the current 60% dependence on fuel wood and reduce deforestation.

A lot of researches have been carried out on the generation of biogas from animal waste. In general, animal manures or wastes digest (or biodegrade) more slowly than other organic matter. Co-digestion refers to the anaerobic digestion (AD) of multiple biodegradable substrates (feedstocks) in an AD system. The addition of codigestion feedstocks can increase the biodegradability and the volatile solids in the digester. Codigestion of various organic feedstocks may enhance the biogas and methane production from an anaerobic digester. In general, the advantages of co-digestion include better digestibility, enhanced biogas production/methane yield arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing (Parawira and Mshandete, 2009).

Studies have shown that co-digestion of several substrates, for example, banana and plantain peels, spent grains and rice husk, pig waste and cassava peels, sewage and brewery sludge, among many others, have resulted in improved methane yield by as much as 60% compared to that obtained from single substrates (Ezekoye and Okeke, 2006; Ilori *et al.*, 2007; Adeyanju, 2008 and Babel *et al.*, 2009). There is therefore a need continue research into the production of biogas from the co-digestion of animal manure and other organic wastes.

Waterleaf (*Talinum triangulare*) is a non-conventional vegetable crop which originated from tropical Africa and is widely grown in West Africa, Asia, and South America (Schippers, 2000). It is a perennial plant that can form dense colonies in shallow water or moist soils. It is a short duration crop which is due for harvest between 35-45 days after planting (Rice *et. al.*, 1986). As the name implies, the waterleaf vegetable is extremely abundant during the rainy season. Paradoxically, waterleaf plant is scientifically classified as a weed. Pig manure has most of the nutrients required for plant growth. However, it contains pathogenic nutrients which could cause health problems in humans if crops grown with pig manure are consumed. Co-digestion of pig manure and grass silage should be adopted for sustainable animal manure management. It can produce methane-rich biogas and nutrient-rich fertilizer, and can reduce the greenhouse gas emissions in the pig industry. Co- substrates, such as agricultural residues, are often needed in order to make anaerobic digestion of pig manure profitable.

Methane, which is a major component of biogas, is produced by termites as part of their normal digestive process; interestingly, termites are the second largest source of global methane emissions (Cooney, 2011).

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MATERIALS AND METHODS

The digester used in this study is a metal prototype digester of 200 liters capacity at the Water resources laboratory of the Federal University of Technology Akure. The digester is shown in Plate1.This research work was carried out between July and August, 2012 at the same laboratory. Other materials used include: weighing balance, distilled water, graduated transparent plastic rubber for measuring volume of gas production, thermometer, hosepipe, burner fabricated for checking gas flammability. The bio-digester has a circular diameter of 540mm with a height of 900mm. It is properly insulated to maintain adequate temperature.

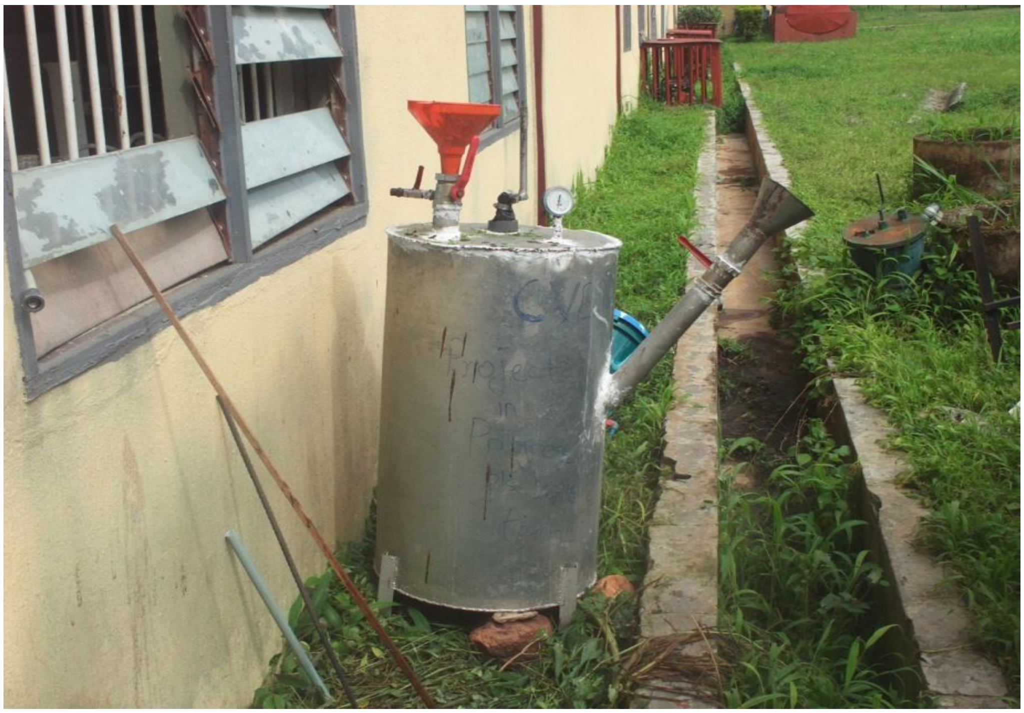

Plate 1: Digester used in this study

Experimental apparatus set up.

The waste samples which comprises of pig dung and water leaf were collected from the different locations both in the university school farm and off campus. The waste samples were first weighed in proportion by the use of weighing balance. A waste volume of 45kg, consisting of 80% of pig dung and 20% waterleaf, was used for the experiment. The waste to water mix ratio adopted in this research was 1: 2.

Charging of digesters

After mixing, the slurry that was formed from the waste sample was fed into the digester gently through the inlet pipe. The water displacement method was used to measure the amount of biogas produced. This consist of a 20 liters white plastic container equipped with two hoses, one connected at one end to the digester to trap the gas produced and the other connected from the other side of the container to the cylinder in order to store the biogas produced .

Gas storage

The gas was collected with the aid of rubber hoses connected with the gas holder of the digester to receive the gas coming from the digester. Gas produced was collected through a water displacement method described by Otun *et al.* (2015) and Ojo *et al.* (2016). This was achieved by using a graduated transparent 20 litres plastic rubber. The container was filled to two-third of its volume with water, leaving the remaining volume for gas measurement.

The readings were appropriately taken at intervals and recorded into a recording sheet. The arrangement for gas collection is shown in Plate 2. A burner was used to check the flammability of the biogas produced.

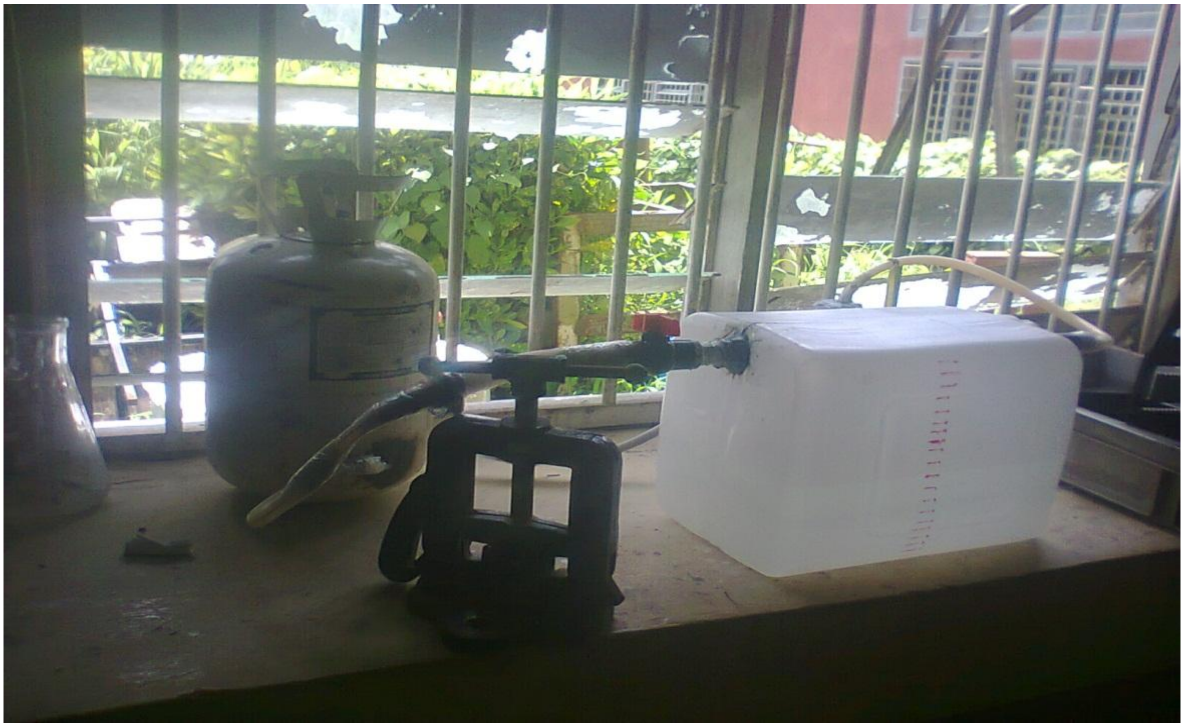

Plate 2: Set-up for gas collection

The wastes (slurry) prepared were charged into the digester gently through the inlet up to two-third of the digester volume leaving one-third head space for collection of gas. The digester contents were stirred adequately and on a daily basis throughout the retention period to ensure homogeneous dispersion of the constituents of the mixture. Gas production measured was obtained by downward displacement of water by the gas.

Experimental procedures

The waste samples which comprises of (pig dung and water leaf) were collected from the different locations both in the university school farm and off campus. The waste were homogenized with the use of wooden stick for proper mixing and subsequently fed into biodigester. The feed stocks were stirred at regular intervals in order to prevent undesirable settling. The biogas produced was measured every day for a 40 day retention period. Ambient and influent temperatures are recorded every day with two hours interval.

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Extraction of enzyme from termite guts

The termites were taken out of their mould and placed in sterilized petriplates. They were then surface sterilized by washing with 70% of alcohol. Each termite was separated into its head and body. After removing the heads with forceps, the bodies were crushed with the help of glass rods. The paste obtained from the termites gut was charged into the inlet of the digester to facilitate the rate of production of biogas.

RESULTS AND DISCUSSION

The trend of the daily and cumulative biogas production from the digester system with and without the aid of enzymes extracted from the gut of termites is presented in Table 1. The experiment was carried out under average ambient temperature range of 24°C - 28°C within a 40 day retention period. Biogas production without the aid of termites started on Day 10 and continued until day 37. The onset of gas flammability was observed on the 15th day, and stopped on the 31st day even though there was still tendency for the production of more biogas. However, gas production stopped completely before the end of the 40 day retention period.

For the termite – aided anaerobic co-digestion process, there was no biogas production from Day 1 to Day 7 as a result of fermentation. It is assumed that during this stage, the waste was decomposing. On Day 8, 90 mL of biogas was produced and biogas production continued slowly until the end of the retention period. It would be observed that there was a clear improvement in the biogas generated from Day 15 and this can be attributed to the catalytic effect of enzyme extracted from termite gut and introduced into the co-digested feedstocks. From Day 15 till Day 40, the biogas production increased significantly and steadily due to the exponential growth of microorganisms. The onset of gas flammability took place on the 12th day, and stopped on the 36th day even though there was still tendency for the production of more gas. After the 40 days retention period, there was still the tendency for more biogas production. This is due to the fact that the carbons contained by all the waste constituents were not equally degraded or converted to biogas through anaerobic digestion. It should be noted that anaerobic bacteria do not or very slowly degrade lignin and some other hydrocarbons. In other words, the higher lignin content will lower biodegradability of waste. The pig dung used in this study contains lignocellulosic rich materials, so anaerobically degradation was rather slow and would tend to be prolonged. This correlates with findings of Wilkie (2005**)**.

Table 1: Biogas production from co-digestion of pig manure and waterleaf using termites as enzyme

Day	Biogas Produced (mL)		Cumulative Biogas Produced(mL)		Average temp.(^{o}C)
	Without termites	With termites	Without termites	With termites	
1	0	0	0	0	26
2	0	0	0	0	27
3	0	0	0	0	25
4	0	0	0	0	26
5	0	0	0	0	28

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6	0	0	0	0	27
7	0	0	0	0	25
8	0	90	0	90	25.5
9	0	30	0	120	26
10	60	20	60	140	24
11	20	20	80	160	25.5
12	20	0	100	160	27
13	30	30	130	190	26
14	0	0	130	190	25
15	20	40	150	230	27
16	10	15	160	245	24.5
17	20	35	180	280	27
18	30	40	210	320	26
19	30	40	240	360	26.63
20	10	0	250	360	25.75
21	0	0	250	360	27.25
22	10	15	260	375	24.75
23	10	0	270	375	23.78
24	0	10	270	385	25
25	0	10	270	395	25.25
26	10	10	280	405	25.2
27	10	15	290	420	25.5
28	0	40	290	460	27
29	20	20	310	480	24.4
30	20	60	330	540	26.75
31	30	80	360	620	25.75
32	30	10	390	630	26.25
33	20	0	410	630	27.95
34	10	60	420	690	25.25
35	20	40	440	730	26
36	10	60	450	790	26
37	10	20	460	810	23.75
38	0	0	460	810	25.5
39	0	20	460	830	24.9
40	0	5	460	835	23.6

CONCLUSION

The result of this study has shown that the co-digestion of pig manure with waterleaf has potentials to produce biogas but may require the addition of enzymes such as that extracted from the guts of termites to increase cumulative biogas yield. The cumulative biogas yield under the 40 day retention period shows that there was a steady and significant biogas yield from the termite- aided co-digestion process and there was still a tendency for continued biogas production after the retention period.

The need to adopt biogas technology as a means of solving the energy demands of Nigerians cannot be over emphasized. The co-digestion of waste materials would ensure better digestibility and increased biogas yield. It is recommended that research should be extended into the investigation different mix ratios of pig manure, water leaf and termite enzyme that can be co-digested to achieve optimum biogas yield.

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