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UTILIZATION OF POULTRY, COW AND KITCHEN WASTES FOR BIOGAS PRODUCTION: A COMPARATIVE ANALYSIS

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ABSTRACT

The amount of solid wastes generated in developing countries such as Nigeria has steadily increased over the last two decades as a result of population explosion and continuous growth of industries and agricultural practices. In agriculture, particularly cattle rearing, large quantities of cow wastes are generated, which could be used as biogas inputs to compliment the fuel usage alternative. In addition, a large number of families generate heavy wastes in the kitchen on a daily basis, which could be converted to economic benefits. In this work, a comparative study of biogas production from poultry droppings, cattle dung, and kitchen wastes was conducted under the same operating conditions. 3kg of each waste was mixed with 9L of water and loaded into the three waste reactors. Biogas production was measured for a period of 40 days and at an average temperature of 30.5^{o}C. Biogas production started on the 7th day, and attained maximum value on the 14th days for reactor 1. Production reached its peak on the 14th day with $85\times10^{-3}dm^3$ of gas produced in reactor 2. For reactor 3, biogas production started on the 8th day and production reached a peak value on the 14th day. The average biogas production from poultry droppings, cow dung and kitchen waste was 0.0318dm^3/day, 0.0230dm^3/day and 0.0143dm^3/day, respectively. It is concluded that the wastes can be managed through conversion into biogas, which is a source of income generation for the society.

Key words: Biogas, wastes, conversion, energy, cow wastes, kitchen wastes

INTRODUCTION

During the past two decades, developing countries and particularly Nigeria has witnessed increased level of waste generation due to population explosion, increased agricultural activities, and the growth of industries. Consequently, there is intense scrutiny of possible alternative of solid waste utilization through biogas production using organic residues, which includes poultry droppings, cattle dung, and kitchen wastes. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment Guruswamy *et al.*, 2003; Alvarez *et al.*, 2006. One technology that can successfully treat the organic fraction of wastes is anaerobic digestion (Hill, 1983; Verma, 2002). It has the advantages of producing energy, yielding high quality fertilizer and also preventing transmission of disease (Koberle, 1995). Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and the presence of anaerobic microorganisms.

The digestion process is carried out using an airtight reactor tank and other equipment used for waste pretreatment and gas retrieval. The process generates a product called "biogas" that is primarily composed of methane (which can be used for cooking), carbon dioxide (which can be used for fire extinguishers), and compost products suitable as soil conditioners on farmlands (Ojolo and Bamgboye, 2005). The final effluent can be used as fertilizer on farmlands and sometimes as animal food additives. Harnessed biogas can either be processed and sold directly or used to generate energy, which can then be sold. Anaerobic digestion also produces savings by avoiding costs of synthetic fertilizers, soil conditioners and energy from other sources.

Exploitation of animal dung for production of

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biogas in Nigeria is in its infancy. The pioneer biogas plants are a 10m^3 biogas plant constructed in 1995 by the Sokoto energy research centre (SERC) in Zaria and an 18m^3 biogas plant constructed in 1996 at Ojokoro Ifelodun piggery farm, Lagos by the Federal Institute of Industrial Research Oshodi (FIIRO) Lagos (Zuru *et al.*, 1998). Approximately 70% of Nigeria's 120 million people live in areas where no formal waste management systems are in place. A recent study assessed Nigeria's biogas potentials (minimum value) from solid waste and livestock excrements. It revealed that in 1999, Nigeria's biogas potential represents a total of $1.382\times10^9 m^3$ of biogas/year or an annual equivalent of 4.81 million barrels of crude oil. This work is a comparative study on the quantity and energy production of five different types of municipal wastes. It is a test for optimization of an anaerobic digestion process, which depends on the waste producing the highest quantity of biogas.

MATERIALS AND METHODS

Material preparation

The experimental wastes were collected from various parts of Lagos State, Nigeria. Cow dung was collected freshly from a cattle farm at the Army cantonment, Ikeja. One-day-old poultry droppings were also collected from a poultry farm at the Army cantonment. Kitchen waste which contained leftovers of cooked rice, plantain, meat, beans, stew, and vegetables, were collected from kitchens of 5 different restaurants at the University of Lagos. The waste samples were stored in black sealed polythene bags to conserve the moisture.

Reactor Setup

Each reactor tank was connected via its gas outlet to a 5L plastic gas collecting apparatus using 12.7mm plastic flexible connectors. The fabricated gas collecting apparatus had a tap, which was used to run-off and measure water displaced by the collected gas. The gas was collected by water displacement method. This was carried out by measuring and recording the quantity of water-displaced daily using a 100mL measuring cylinder. The experimental set-up was as reported by Ojolo and Bamgboye (2005).

Experimental procedure

About 3kg from each waste was weighed and then mixed thoroughly with about 9kg of water for optimum gas production. This was then loaded to about 3/4 of the digester volume. The reactor inlet openings were tightly sealed to exclude oxygen. The reactor tanks containing substrates of cow dung, poultry drippings and kitchen wastes were labeled as reactors 1, 2 and 3, respectively. The tanks were subjected to periodic shaking to ensure thorough mixing of the digester content while maintaining intimate contact between the microorganisms and substrate and to enhance complete digestion of substrate. The volume of biogas yield was measured and recorded on a daily basis. The experiment was monitored for 40 days and was repeated for three consecutive times for each substrate. During this period, daily ambient temperature varied from 27ºC to 32ºC.

RESULTS

Table 1 shows the total biogas produced, the biogas yield per day and the biogas yield per kg slurry from each reactor. The quantity of biogas produced from the cow, chicken, vegetable, fruits and kitchen wastes over a period of 40days and an average temperature of 30.5ºC is shown in Fig. 1. Tables 2a and 2b contains the results of the Anova results: Two-Factor Without Replication. The experimental setup for the pilot study is shown in Fig. 2.

Table 1: Total biogas produced from cow, poultry and kitchen wastes$\times10^{-3}dm^3$

	Reactor 1 (cow dung)	Reactor 2 (poultry droppings)	Reactor 3 (kitchen waste)
Total biogas produced	690	955	430
Average yield per day	23	31.8	14.3
Biogas yield/kg slurry	57.5	79.6	35.8

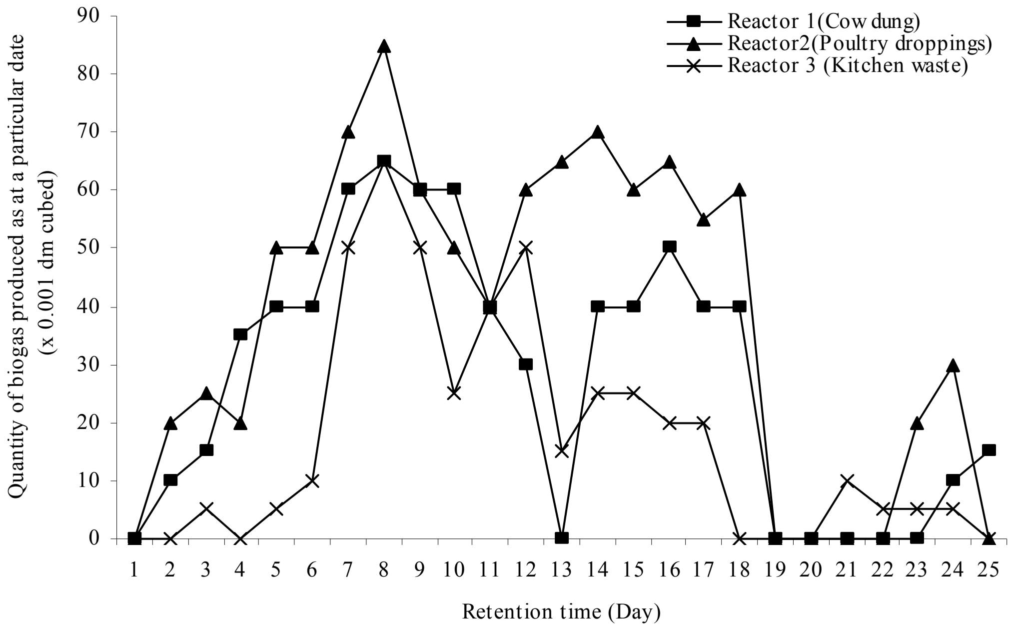

Fig. 1: Biogas production from cow, poultry and kitchen wastes

Table 2a: Anova results: Two-factor without replication

Summary	Count	Sum	Average	Variance
Total biogas yield	3	2075	691.6667	68908.33
Average yield per day	3	69.1	23.03333	76.56333
Biogas yield/kg slurry	3	172.9	57.63333	479.6233
Reactor 1 (Cow dung)	3	770.5	256.8333	141022.6
Reactor 2 (Poultry droppings)	3	1066.4	355.4667	270151.4
Reactor 3 (kitchen waste)	3	480.1	160.0333	54777.06

Table 2b: ANOVA results

Source of variation	SS	df	MS	F	P-value	F crit
Biogas yields	850266	2	425133	20.83064	0.007674	6.944276
Reactors	57292.96	2	28646.48	1.403619	0.345285	6.944276
Error	81636.08	4	20409.02			
Total	989195	8				

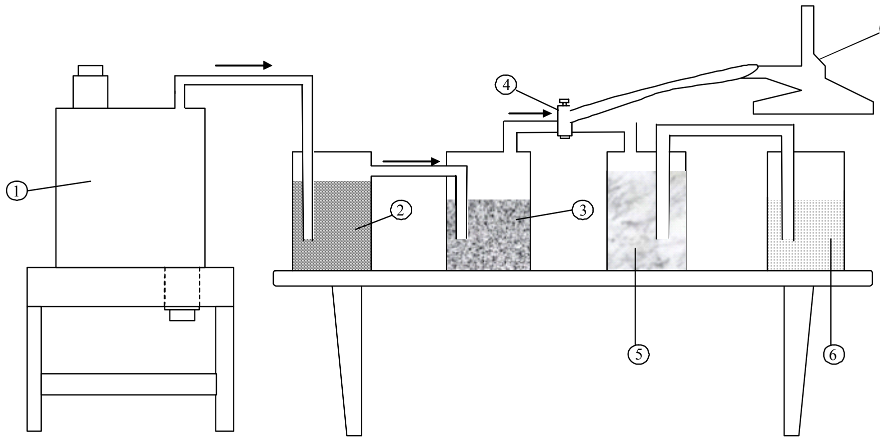

Fig. 2: Schematic diagram of the anaerobic digestion experiment

DISCUSSION

Referring to Fig. 1, biogas production started in two of the reactors 1, and 2 on the 8th day (day 2, retention time axis of Fig. 1) after loading while production in reactor 3 commenced on the 9th day. The Figure also shows the total biogas production from each of the reactors and suggests that reactor 2 produced the highest quantity of biogas (0.955dm^3) in 40days while reactor 3 produced the least (0.430dm^3). These yields were higher than that obtained by Mahnert *et al.*, (2005) for three grass species. This can be traced back to the presence of more cellulose materials in grass than in the wastes considered in this work. Fig. 1 also shows the biogas yield from the reactors over the retention period. It can be seen that biogas production started in trace quantities on the 7thday (day 1, Retention time axis of Fig. 1) increased gradually on subsequent days then suddenly attained maximum value on the 14thdays for reactor 1. Production then dropped drastically and further production after the 25thday was in little quantities. Production reached its peak on the 14thday with 85×10^{-3}dm^3 of gas produced in reactor 2. There was no production from the 25thday until the 29th. The lag period of 7-8days observed in this work for cow, poultry and kitchen waste is higher than 3-4days reported by Zuru *et al.*, (1998) and lower than 15days reported by Lucas and Bamgboye (1998) probably due to the fact that the wastes were not well pre-treated

From reactor 3, biogas production started on the 8thday and production increased on subsequent days until it reached a peak value on the 14thday. Production ceased after the 23rdday and resumed on the 27thday. Reactor 2 had the most stable and consistent biogas production over the retention period. Biogas production started on the 8thday, increased gradually and peaked on the 14thday. On the 25thday, there was no production until the 29thday when there was unexpected biogas production. Average biogas production from poultry droppings was 0.575kg/dm^3 for cow dung and 0.796kg/dm^3 for poultry droppings. This result is higher than that obtained by Monnet's (2003) where biogas production from chicken droppings was 0.60dm3/kg and biogas production from cattle waste was 0.30dm^3/kg. The current study shows a similar order to Srinivasan's (2005) work.

It was observed that daily biogas production from cow and poultry waste (0.230dm^3–0.318dm^3) was higher than that of kitchen waste (0.143dm^3) probably because cow and poultry wastes have undergone initial digestion in the animals' stomach. Also, there are some inhibitors (oil, fats) in the kitchen waste, which could have limited the production of biogas from this waste. The fact that scum was observed during the off loading of the digested contents of reactor 3 is a clear indication that biogas yield from it will be far less than those obtained from reactors 1 and 2.

From the gas production analysis, the average methane content was maximum in poultry droppings producing 0.069m^3/kg slurry. Other feedstock used were pig dung, which produced 0.058m^3 biogas per kg slurry and cattle dung producing 0.037m^3/kg slurry. This may be due to higher nitrogen content (5.9%) and favourable pH of 7.01 in poultry droppings as compared to other feedstock. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. Substrates should contain adequate amount of carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and a number of trace elements for biodigestion (Kanwar and Kalia, 1992). From Table 1, Reactor 2 had the most biogas yield per day producing 31.8×10^{-3}dm^3 per day while reactor 3 had the least biogas yield per day producing 14.3×10^{-3}dm^3. Reactor 2 also had the highest biogas yield per kg slurry producing 79.58×10^{-3}dm^3 per kg slurry while reactor 3 had the least biogas yield per kg slurry producing 35.8×10^{-3}dm^3 per kg slurry.

Looking at the biogas production as treatments and the reactors as blocks (Table 1), an analysis of variance table and test at the 0.05 level of significance was carried out to test whether there are differences in the biogas production or in the reactors (Miller and Freund, 1987). The solution involves formulating the null and alternative hypotheses. Where α_i, which is the effect of the ith treatment, β_i, the effect of the jth block were each equated to zero. The alternative hypothesis indicated that they are not equal. The criteria is that for treatments, the null hypothesis may be rejected if F>6.94, the value of $F_{0.05}$, with 2 and 4 degrees of freedom. For blocks, the null hypothesis is rejected if F>6.94, the value of $F_{0.05}$, with 2 and 4 degrees of freedom. Concerning decision, since F_{tr}=2.083 exceeds 6.94, the value of $F_{0.05}$ for 2 and 4 degrees freedom, it is concluded that there are differences in the level of production of the three parameters that serve as indicator for biogas production. However, since F_{bl}=1.40 does not exceed 6.94, it is concluded that there are no differences among the reactors. Thus, any of the three designs may have been appropriate for the experiment.

To conclude, the cumulative biogas yield from 12kg (1:3 waste to water ratio) slurry of poultry droppings, cattle dung, and kitchen waste digested over a period of 40 days and average ambient temperature of 30.5^{o}C was found to be 955, 690 and 430×10^{-3}dm^3, respectively. This shows that poultry droppings produced the highest amount of biogas followed by cattle dung and kitchen waste. Poultry droppings produced more biogas because it contains more nutrients and nitrogen compared with other animal waste except pig waste. The higher biogas production from poultry droppings could also be attributed to the available nutrient in the droppings. According to Hill (1984) substrates should contain adequate amount of carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and a number of trace elements. From this work, animal waste produced more biogas than kitchen wastes because the latter were not well pre-treated (shredded). Shredding allows for better and more contact between the active microorganisms and the slurry, and improves the bacterial population's ability to obtain nutrients, which in turn increases biogas production. For digesters without a good stirring mechanism, mixing or shaking the digester is very important as it prevents scum formation and avoids temperature fluctuations within the digester. Providing adequate mixing facilities can reduce the scum formation during anaerobic digestion. Lack of an adequate mixing of the substrate will hinder the elimination of artificial barrier created over the surface of the substrate due to scum formation.

Biogas production from poultry manure of large farms is an ecologically and economically effective technology. Greater percentage of COD reduction can take place with larger biogas volume produced for every proportion of degraded organic matter with 15-40days retention time. Aggressive odour could be removed, a greater number of pathogens could be reduced, and organic nitrogen could be converted to ammonia, thereby reducing environmental hazards (Gunaseelan, 1987). The main disadvantage of chicken manure is that it

produces a proportion of hydrogen-sulphide, which, even when present in only small proportions, corrodes metal fittings. (It is also poisonous, but not in the quantities produced so there is never likely to be enough to be a danger). When it burns in air it oxidises to sulphur-dioxide. Cow dung produces almost no hydrogen-sulphide but needs larger quantities than chicken to produce the same amount of gas. From the results of this work, it can be concluded that the wastes generated from domestic and agricultural activities could be converted into useful products (methane and manure) with the help of anaerobic digestion technology.
Based on the results of this study, the following recommendations may be considered:

More attention should be given to poultry droppings as feedstock for anaerobic digestion plants. Digestion plants that use poultry droppings as feedstock should be situated in areas where there are many poultry farms. Poultry droppings from these farms could be gathered on a daily basis at a low cost and used to run the plants. A poultry farm could also be situated within the digestion plant to compensate for shortcomings of the external farms and to make the plant an independent system. If the biogas produced is going to be used to run engines, it has to be cleaned because it contains impurities that can damage boilers and engines.

Kitchen waste to be used as feedstock for digestion plants should be well pre-treated for more biogas production. Also, Oil in feedstock should be reduced as much as possible as this forms scum.

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