



Production and Testing of Biogas Using Cow Dung, Jatropha and Iron Filins

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Abstract: Biogas production was investigated in this study as an alternative to wood as fuel using slurries of cow dung (T1), jatropha fruit exocarp (T2), cattle dung and jatropha fruit exocarp (T3) and cow dung, jatropha fruit exocarp with 10 g of iron filings (T4). The 1000 mL of slurry which included 50 mL of inoculum that compensated for the dead or weak micro-organism was made for each sample. At the end of five weeks, the volume of biogas collected from the samples T1, T2, T3, and T4 when added up, gave 77, 154, 145 and 586 mL, respectively. The sample mixture of cow dung, jatropha fruit exocarp, and iron filings (T4), gave the highest yield of biogas production with an average weekly production of 59 mL/kg for four weeks and on the fifth week about six times emission of biogas was obtained. The production rate of the biogas was rapid after the gestation period and the T4 emerged as the most substantial emission of all the samples producing 350 mL/kg on the fifth week.

Keywords: anaerobic; digestion; bacteria; biodegradable; biogas

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1 Introduction

Energy is a core requirement for economic and social development of a nation. It facilitates domestic and industrial activities. Energy can broadly be grouped into renewable and non-renewable energy (Al Seadi et al., 2008; Sahu, 2015; Ibitoye, 2018). The renewable energies are replenishable over a short period of time, cheaply available and environmentally friendly. Examples of such energy are solar, wind, tidal and geothermal energy, while the non-renewable energy takes a long period of time to replenish, causing environmental degradation and already tending towards extinction (Ahamed et al., 2016). Due to high level of industrialization and urbanization, the demands for energies have greatly increased such that the available sources cannot meet the ever-increasing demand (Pavithran et al., 2015; Faisal et al., 2018; Izquierdo et al., 2018). In addition, the increase in price of fossil fuel products such as gasoline, kerosene and diesel has made the people living in the rural areas and some urban poor to seek for an alternative source of fuel for energy generation (Richards et al., 1994). This has led to continuous cutting down of trees as fuel, resulting in high level of deforestation and environmental degradation which is now a global concern. Forests are being depleted everywhere around the world especially in Africa (Ibitoye, 2018). Forests are being cleared, degraded and fragmen-

ted by road constructions, agriculture activities, timber harvest, human-caused fire, and other numerous ways. Originally, most of the tropics were covered by forest; half of the USA, three-quarters of Canada, almost all of Europe, the plains of the Levant and greater part of the world were covered by forest (Neelkanthan, 1976; Bagudo et al., 2011). The forest has been mostly removed for fuel, building materials and to clear land for agriculture. The deforested lands are now laid open to soil erosion, flood, wind storm, landslide, and avalanche in snowy regions which also contributed to global warming.

These effects can be reduced if not eliminated by encouraging afforestation, sensitizing the people of the effect of deforestation and finding an alternative to wood as major sources of fuel in the rural areas and some part of the urban occupied by the poor. Alternatives to wood as fuel are biomass briquetting, solar energy, wind energy, pelletization, cubing of combustible biomass residues and biogas production (Corro et al., 2014). Biogas is a mixture of gases which is produced by breaking down organic substances in the absence of oxygen. It can be generated from materials such as agro-residues, municipal wastes, manure, and sewage food waste among others (Singh et al., 2010). Biogas has several advantages which include reduction of water and soil pollution, producing organic fertilizer, and encouraging circular economy and

being eco-friendly (Jürgensen, 2015). It has several disadvantages as it contains impurities, production is temperature dependent, not suitable for large population, and could not be produced in large quantity (Nahar et al., 2017). Factors that affect biogas production are the effect of agitation on the yield, pH of the digester content, loading rate, salinity, microbial activities among others (Vasileiadis et al., 2012; Aoyi et al., 2015).

Johnny et al. (2018) and Ahamed et al. (2016) carried out an investigation on biogas production using silica gel as catalyst. Laboratory scale digester was used to produce the biogas from poultry droppings and domestic kitchens wastes. Two digesters were used, one with silica gel and the other without silica gel. The temperatures of the digesters were maintained between 26°C and 31°C. The researchers adopted water displacement method to investigate the quantity of gas produced. Johnny et al. (2018) reported cumulative biogas production of 8924 mL/kg for setup without silica gel and 11 245 mL/kg with silica gel as catalyst while Ahamed et al. (2016) reported 628 mL/kg and 10 545 mL/kg for samples without catalyst and with silical gel as catalyst respectively.

Bagudo et al. (2011) analyzed the influence of catalyst (yeast) on the biomethanization of selected organic waste materials. It was found that addition of catalyst improved the quality and quantity of biogas generated and also fastened the gas formation stages during biomethanization. The volumes of biogas in the catalyzed process were found to be 6550, 5640, 3240, 1000, 800 cm³ for cow dung, millet husk, rice husk, saw dust and paper wastes respectively against 5430, 5230, 2110, 950, and 590 cm³ respectively for the uncatalyzed biomethanization process.

This study considered a method for rapid production of biogas from a mixture of cow dung, jatropha fruit exocarp and a catalyst. It is expected that the findings will enhance the use of biogas by making it more available and cheaper and will reduce deforestation and global warming.

2 Materials and Methods

2.1 Materials

The materials used for the tests were one liter plastic containers, four in number; the 330 mL calibrated plastic containers, four in number, 160 mL plastic cup, 4.2 m × 0.8 cm diameter hose, plastic hollow bolts and nuts, rubber seals, washers and hose clips.

2.2 Methods

The method adopted in this study is similar to the method of Ahamed et al. (2016). Each of the one liter plastic containers was thoroughly washed and conditioned for growth of micro-organisms. They were perforated at the top, close to the lid and made airtight using washers and rubber seals. Hoses, clips and rubber seals were used to

secure an airtight link between the one liter containers and 330 mL calibrated plastic container shown in Fig. 1. The 330 mL calibrated bottle for gas collection was made airtight and inverted. A 0.8 cm hose fitted into the inverted calibrated bottle was made to discharge water into a measuring container. At the start of each experiment, the calibrated plastic bottle was filled with water and inverted as in Fig. 1. As biogas was discharged from the digester, it entered the inverted jar filled with water which was made free from undesirable gases. The biogas was first measured by the calibration on the inverted jar and was then confirmed by the volume of displaced water collected in the measuring container. Four sample tests, T1, T2, T3 and T4 were carried out. The T1 contained cow dung (CD) only, the T2 contained jatropha fruit exocarp (JFE) only, the T3 contained a mixture of CD and JFE at the ratio of 3:1 and the T4 contained CD, JFE and 10 g of iron filings (Fe). The iron fillings used were in the solid state and of 10 micrometer particle sizes. The composition for each sample tested for anaerobic digestion is shown in Table 1. Slurry volume of 1000 mL was made for each sample from which 630 mL was used to make a mixture for the first test T1. The second test T2 used 640 mL, the third T3 and fourth T4 used 600 mL, respectively. The slurries were mixed with a stirrer and left for seven hours before being used for the experiment. The experiments were carried out between the months of April and June at an average temperature of 36°C.



Fig. 1 Experimental setup for biogas production

An inoculum of 5% of the feedstock was used to assist the anaerobic digestion of the individual treatment and was prepared by composting fresh cattle dung for the period of six days, under ambient temperature (Bagudo et al., 2011; Wang et al., 2016). As a result of active micro-organisms contained in fresh cattle dung, 50 mL of inoculum were added to each of the four samples in order to compensate for the dead or weakened micro-organisms in the various sample treatments. The experiment carried out in duplicates and the averages were calculated.

The anaerobic digestion by chemical reaction stages are (Fig. 2):



Table 1 Composition of treatments by mass and volume

Sample	CD (g)	JFE (g)	CD, JFE (g)	Fe (g)	CD, JFE, Fe (g)	Slurry (mL)	Water in slurry (mL)	Inoculum (mL)	Total slurry (mL)
T1 (CD)	172.108	0	0	0	0	630	320	50	1000
T2 (JFE)	0	57.369	0	0	0	640	310	50	1000
T3 (CD, JFE)	0	0	229.477	0	0	600	350	50	1000
T4 (CD, JFE, Fe)	0	0	0	10	239.477	600	350	50	1000

Notes: CD, cow dung; JFE, jatropha fruit exocarp.

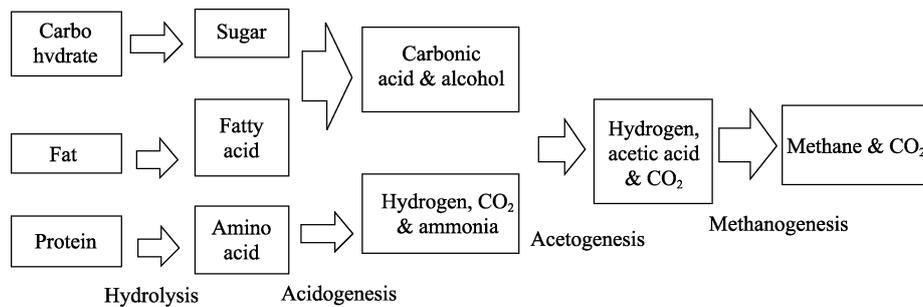


Fig. 2 Stages of anaerobic digestion to produce methane (Ahamed et al., 2016)

3 Results and Discussion

Figures 3–7 show the daily biogas production for the first five weeks of the experiment. In the first day of the experiment; CD (T1), JFE (T2) and mixture of CD with JFE (T3) did not produce any biogas because of the slow chemical digestion; while the mixture of CD, JFE and Fe as catalyst (T4), produced 2 mL/kg of biogas (Fig. 3). Daily increase of biogas production was observed for T2 and T3, however, the curves of T3 and T4 appeared similar except for the greater gestation of T4 over T3 during the 2nd, 3rd, 4th and 6th days of about 3 mL/kg. On the 7th day of the experiment, biogas production was less in T3 when compared with T4 in the ratio of 3:5. For T1, digestion commenced on the 2nd day with production of 1 mL/kg of biogas which was maintained through to the 3rd day, the digestion increased to produce 2 mL/kg of biogas on the 4th day and increased to the highest of 3 mL/kg on the 7th day. This is because at the first day of experimental setup, the microorganisms responsible for the process were completely inactive. Aerobic bacteria

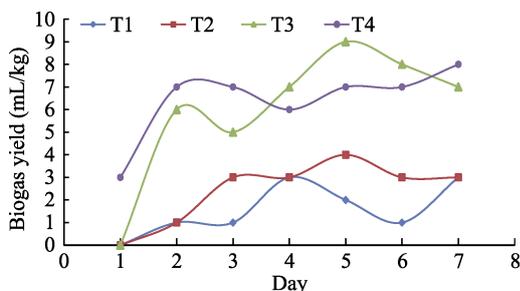


Fig. 3 Biogas daily yield collection for one week

presenting in the raw materials were making use of the oxygen which presented in the digester during this period and when the oxygen had been exhausted acid forming bacteria became active and the digester began to produce gases.

Figure 4 shows that T1 changed a little with ± 1 mL/kg while T2 digested and released more biogas with time in 11–14 d of the experiment, than all the other tested samples. The T2 recorded biogas volume of about 13 mL/kg in the 12th day of the experiment which was the highest for all the tests over two weeks period of test. This might be due to quick commencement of the anaerobic action of the bacterial presenting in the sample and could also be due to the type of the material and surrounding temperature. The iron fillings inclusion in T4 affected the biogas digestion giving a discharge of 12 mL/kg on the 12th day of the test. Horn et al. (2015) reported that water hyacinth fermentative production of hydrogen and ethanol was feasible and was significantly affected by iron nanoparticles. Further explanation was given that activities of the enzymes presenting in methanogenesis and acidogenesis could be

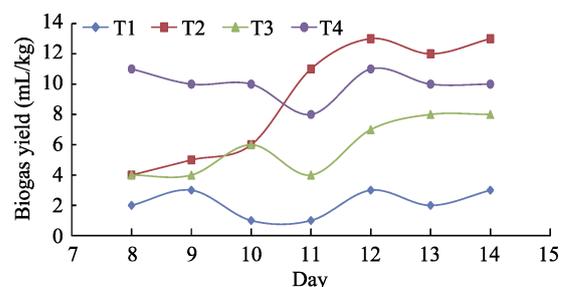


Fig. 4 Biogas daily yield collection for two weeks

stimulated by iron particles due to its ability to enhance basic elements in metallo-enzymes and to improve the stability of cellulose enzymes which enhanced the catalytic production of biological and chemical digestion.

The biogas output on the 3rd week of test is shown in Fig. 5. Again the sample T2 was observed to have produced the highest with about 11 mL/kg of biogas on the 16th, 20th and 21st days shown in Fig. 5. The samples T2 and T4 maintained an average biogas production of 9 mL/kg per day on the 3rd week. The T3 and T1 settled to an average biogas production of about 4.6 and 2.0 mL/kg per day respectively on the 3rd week.

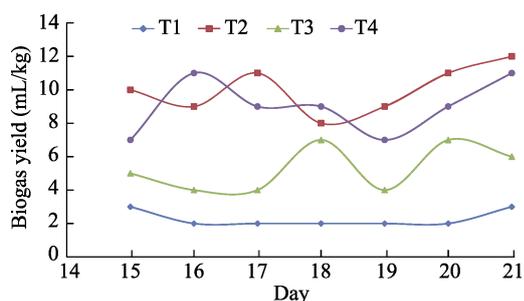


Fig. 5 Biogas daily yield collection for three weeks

As shown in Fig. 6, on the fourth week of test, T2 reduced in biogas production to 3 mL/kg on the 22nd day, 4 mL/kg on the 23rd day and 2 mL/kg on the 24th day when it stopped totally. Ahamed et al. (2016) also experienced zero production on the 18th, 20th and 21st day using poultry dropping, domestic waste and silica gel as catalyst, respectively. Johnny et al. (2018) experienced zero out on the 18th, 20th and 21st perception days of biogas production using kitchen waste. It might be as a result of inactivity of the microorganism and need for an inoculum. Average of T1 was 3.2 mL/kg per day, which was slightly higher than that of the third week. The T3 increased by an average of 5.4 mL/kg of biogas during the 4th week with a maximum emission of 7 mL/kg on the 25th day after test was started and T4 emitted biogas of 8 mL/kg on average with a maximum of 10 mL/kg on the 23rd day of test. In the 18th, 20th and 21st observation days, there was no gas production from the system.

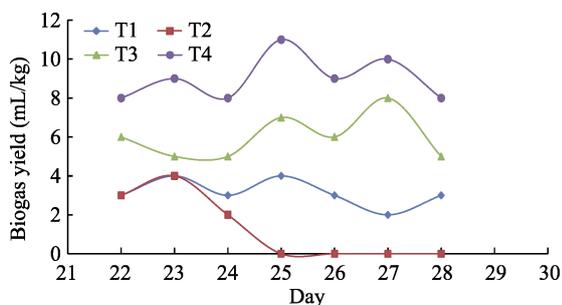


Fig. 6 Biogas daily yield collection for four weeks

The anaerobic digestions which were initiated from the first day of the first week of the sample tests showed that emission of biogas only commenced on the second day of the test. It continued to increase as the weeks went by until the fifth week when digestion stopped completely for test sample T2 (Fig. 7). The T1 was stable with a 2.6 mL/kg release of biogas on average. The T3 produced 7 mL/kg on the 32nd day of the test, average 4.9 mL/kg of biogas production and was stable. The sample T4 became active on the 5th week of the test when it produced about 6 times biogas than it did during the previous weeks. This was a significant increase which was due to the addition of catalyst that enhanced the bacterial activity just like chemical reaction could be enhanced by the addition of catalyst. Similar observation was made by Ahamed et al. (2016) and found that production rate increased during 7th–24th days of the test. It reported that the increase output was as a result of catalyst that was included in the mixture. Bagudo et al. (2011) produced biogas from cow dung, millet husk, rice husk, and saw dust and paper waste, and they found that addition of catalyst enhanced bioconversion and increased digester output. Gumel et al. (2013), Hornm et al. (2015) and Faisal et al. (2018) reported that types and concentration of particles of the catalyst played a vital role in the production rate of the anaerobic digestion system. Therefore, iron filling catalyst is the major factor responsible for the substantial increase in biogas production among other factors such as temperature of the environment.

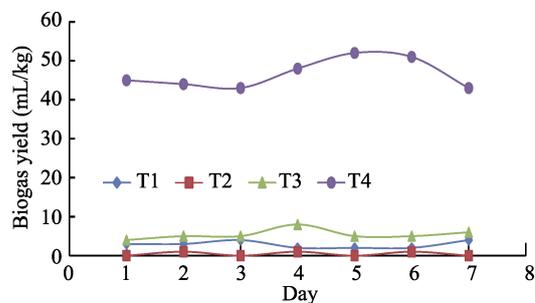


Fig. 7 Biogas daily yield collection for five weeks

Figures 8 and 9 show the total biogas production collected for each week and cumulative biogas production for each sample during the five weeks of the test respectively. Samples T1 and T3 gave an averaged production output of 13.4 and 36 mL/kg of biogas per week, respectively. The T2 produced 62 and 68 mL/kg of biogas on the 2nd and 3rd week respectively. There was slower digestion on the first week when the T2 produced 15 mL/kg of biogas and on the 4th week when it was 9 mL/kg. The sample T2 stopped emission after the 4th week. The sample T4 gave an average weekly biogas production of 59 mL/kg for the four weeks of the test

(Fig. 8). However, on the fifth week of the test, about six times emission of biogas was recorded for the experiment. The production of 350 mL/kg of biogas was recorded on the fifth week for the T4 and the experiment was run up to the tenth week. The maximum biogas production of 395 mL/kg was observed at the sixth week of the experiment and was noted with the sample T4. Catalysts (iron fillings) enhanced the activity of bacterial or microorganisms responsible for the bio-digestion. The iron fillings mitigated pH reduction and increased chemical oxygen demand concentration in the effluent, and it stimulated the reaction of the organic substrate with methanogens to release biogas via methanogens, bio-stimulating mechanisms and digestion of the organic waste. After the sixth week, the daily biogas production of the T4 started reducing and it might be as a result of the reduction of the activities of the micro-organism and catalytic property of the iron filling. The samples T1, T2 and T3 stopped generating biogas after the seventh week of the experiment.

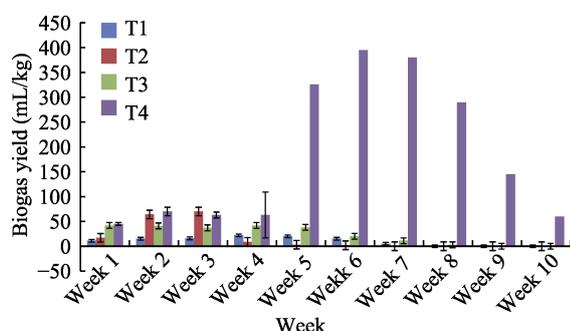


Fig. 8 Graph of total biogas yield against weekly collections

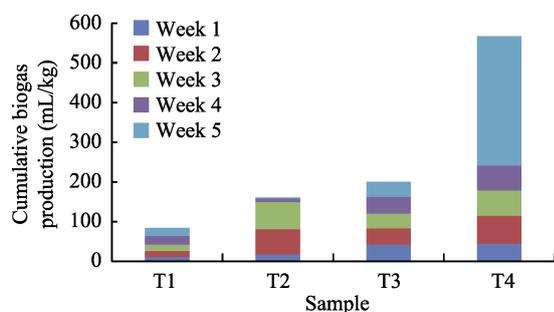


Fig. 9 Cumulative biogas production for each sample for five weeks tested

4 Conclusions

The addition of iron fillings as catalyst actually enhanced the production of biogas which became more active after the fourth week of the experiment. Average weekly biogas production of 59 mL/kg was observed for the first four weeks and on the fifth week of the test; about six times emission of biogas was recorded as a result of the activity of the catalyst. The cumulative biogas production indicated that jatropha exocarp was more viable for

biogas production than the cow dung. The blend of the two samples gave better results than the cow dung; however, the result was not as good as jatropha exocarp only. The cumulative biogas collected for the samples T1, T2, T3, and T4 at the end of five weeks were 77, 154, 145 and 586 mL, respectively.

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