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Biogas Production Using Cow Dung and Sawdust

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Abstract- An investigation of the biogas generation capacity of sawdust and its mixture with cow dung in the ratio (1:2) was conducted. The experiment was performed in a 30-litre digester containing water, cow dung, and sawdust in a 3:1:2 ratio. Mineral elements such as Boric acid, $NiSo_4$, and $CoSo_4$ were added as micronutrients to improve methanogenic activity. The setup was allowed to undergo anaerobic digestion and monitored for a retention period of 20 days at temperatures ranging from 0 ℃ to 37 ℃ and pH levels ranging from 4.3 to 5.4. The results showed that the combination of sawdust and cow dung had a cumulative gas yield of 20.9g after 20 days with a significant increase noticed with increasing temperature. According to the study, sawdust that is either bur.8/ned off or tossed away creating problems for the environment would be an excellent fuel for biogas generation. It also indicated that mixing sawdust with cow dung will offer continuous gas flammability throughout the digestion phase of the waste. The theory of waste to energy is supported by the generation of biogas from sawdust for improved sustainable development.

Keywords- Anaerobic Digestion, Biogas, Cow dung, Digester, Sawdust

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1 INTRODUCTION

Biogas is a clean and renewable energy source that is produced from biomass by anaerobic digestion (AD), a sequence of spontaneous events. Biogas as a fuel helps to solve the world's energy dilemma and will soon become a need owing to the depletion of oil reserves (Ganzoury & Allam, 2015). Furthermore, rising crude oil prices have compelled countries around the world to consider alternative energy sources. Solar energy is the most efficient of the various energy options available and it can even provide plant environmental protection (Mekhilef et al., 2011). The utilization of biogas and consequently methane capture are of a great benefit in resolving the global warming issue as methane global warming impact is 25 times greater than carbon dioxide impact (Mansour et al., 2020). Plants are known for converting and storing massive amounts of solar energy in biomass, and harnessing these energy stores will be the most effective way to replace all fossil energy resources in the future (Deublein & Steinhauser, 2008).

Unfortunately, new alternative energy sources such as solar, hydro, wind, and others require significant financial and technical resources to operate, which appear to be difficult for developing countries such as Nigeria. Biogas technology has the potential to alleviate energy poverty, which has been a major impediment to Africa's economic development. Anaerobic digestion is a waste-to-energy technology that is widely used to treat various organic wastes, such as the organic fraction of municipal solid waste, sewage sludge, food waste, animal manure, and so on (Franca & Bassin, 2020).

Anaerobic treatment entails the decomposition of organic matter in the absence of free oxygen, resulting in the production of methane, carbon dioxide, ammonia, and traces of other gases, as well as low-molecular-weight organic acids (Lopes et al., 2004). Biogas is a biological gas produced by bacteria during the biodegradation (fermentation) of organic matter (from plants, animals, and occasionally humans) in an anaerobic (oxygen-free) environment (Saleh & Hassan, 2021). Biogas is a combustible gas rich in methane (CH4) and liquid effluent created by anaerobic conversion of organic materials into a sustainable energy source (Holden et al., 2021) Methanogens (methane-producing bacteria) are the final link in a chain of microorganisms that decompose organic matter and release decomposition products back into the environment.

According to Ntengwe et al. (2010), the amount of acid formed by any biomass is dependent on the type of biomass because different gas production rates have been observed for different biomass. Cow dung has a high nitrogen content and is the best material for producing high yields of biogas in studies conducted over the years (Ukpai & Nnabuchi, 2012). According to Kasisira and Muyiiya (2009), 100 percent pig manure is can be compared to the same amount of cow dung, it produces more gas per unit weight. Other biogas research has looked into the use of poultry dung, grasses, swine dung, Bambara nut, and other materials. In their quest to improve and optimize the quantity and quality of biogas produced from organic waste, Uzodinma and Ofoefule (2009) discovered that combining field grass with rabbit, cow, swine, and poultry wastes increased the biogas yield of field grass.

According to researchers, blending cow dung with poultry wastes minimizes the duration between gas formation and gas flammability (Ofoefule & Uzodinma, 2006). Adding the appropriate chemicals to the mix before anaerobic digestion, on the other hand, may increase the quantity and quality of biogas generated. Consequently, this study looks at ways to improve biogas

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production from cow dung by mixing it with sawdust and other mineral elements such as Boric acid, NiSo4, and CoSo4 as micronutrients, which increases methanogenic bacteria activity, lowers time lag, and improves overall gas quality.

2 MATERIALS AND METHODS

2.1 SAMPLE COLLECTION

Cow dung (CD) was collected from the Federal University of Technology Akure farm, which is located near the campus's south gate. For this study, 2 kilograms of CD were collected. To ensure homogeneity, the cow dung was sun-dried and then mechanically crushed with a mortar and pestle. The sawdust used was obtained from Ajani sawmill, Owo, Ondo State, Nigeria.

2.2 INSTRUMENTS USED

The instruments include a Bioreactor (prototype) of 30-liters capacity; Speriam gas analyser, made in the USA: Mercury in glass thermometer (0 100-C); pH meter (SEARCHTECH), made in the USA, Weighing balance (50kg capacity) incubator, micro Kjeldahl. Other equipment used includes Test-tubes, Beakers, Conical flasks: Syringes; Measuring cylinders (Pyrex): Crucible; Buchner funnel; Oven: Funnel; hose pipe; water trough graduated (transparent) bucket, glue, hack saw, steel tape.

2.3 MATERIALS

The materials used include: (i) 30 litres cylindrical digester. (ii) 6.25mm hand valve (iii) Flexible rubber hose (iv) Abro gum (v) Spanner and wrench (vi) Hose adapter (lock nut) (vii) Infusion(syringes) (viii) Thermometer (ix) Pressure gauge (x) Iron elbow (xi) Tyre tube.

2.4 METHODS

2.4.1 Experimental Setup

The digester and its components (i.e., gas outlet, slurry inlet, slurry outlet) were fabricated and made airtight. The collection tube that was used for this project was set up in place respectively. Fresh cow waste and sawdust (not mixed with other materials such as wood shaven) were fed into the digester through the slurry inlet of the digester. 15 litres of water were added to the mixture of cow dung and sawdust, which were fed into the digester and stirred thoroughly to break up the lumps in the waste and make it homogenous. The process led to a combined 22 litres of water and waste (cow dung and sawdust). The water source used was tap water. After feeding the digester, a 6mm-diameter hose was connected from the gas outlet on the digester to the collecting gas tube.

Fig. 1: Bioreactor used for digestion.

2.4.2Charging of Bioreactor

The different materials obtained were weighed and mixed thoroughly in water. The mixtures were charged into the 30-litres prototype batch bioreactor. The waste was charged up to 3/4 of the bioreactor volume, leaving headspace for gas collection. The bioreactor was properly coated with the valve locked to exclude air. The bioreactor contents were stirred adequately (50 periods per minute) daily throughout the retention period to ensure homogenous dispersion of the substrate and microbes in the mixture.

2.4.3Determination of Quantity of Biogas Produced

The quantity of biogas produced in grams was obtained by downward displacement of water by the biogas daily. In downward displacement of water, the gas enters the container and forces the water down as the top of the container fills with gas which is then collected through the pipe to the tube. It is insoluble in water and lighter than air.

2.4.4 Determining pH of the Slurry in the Bioreactor

The pH of the slurry was measured every day with a pH meter (Search Tech, model PHS 3C). Before and after stirring, samples of the slurry were taken, and the pH was measured with a pH meter at 7-hour intervals.

2.4.5Moisture Content Determination

Initially, 10 g of the pre-treated material was weighed in a dish that was heated in a 110°C oven. The weight was taken after every 10 minutes until a steady weight was attained (final weight). Equation (1) was used to calculate the moisture content:

$$\%\text{Moisture content} = \frac{final\ weight - initai\ weight}{initial\ weight} \times 100\ldots\ldots(1)$$

The moisture content was evaluated using the **ASTMD 2867-91** standard test.

2.4.6 Determination of the Bioreactor's Ambient and Slurry Temperatures

After charging the bioreactors, the ambient and slurry temperatures of the bioreactors were measured at 9-hour intervals during the retention period with a mercury in glass thermometer (0-100) °C. The temperature of the slurry was determined by dipping the mercury bulb in the slurry and holding it at the thermometer's tip. When

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the mercury reading in the glass had been stable for one minute, the temperature was obtained.

2.5 DETERMINATION OF BIOGAS FLAMMABILITY

A fabricated gas burner was used to test the flammability of the biogas generated. A pipe hose was used to link the constructed gas burner to the bioreactor's valve (tap). After that, the valve was opened to allow gas to flow through the hose to the gas burner, which was then lighted.

3 RESULTS AND DISCUSSION

3.1 MOISTURE CONTENT AND PH

The results of the pH determination and moisture content of the substrates are presented in Table 1.

Table 1. pH and Moisture Content

Properties	Cow Dung	Saw Dust
Moisture content (%)	5.7	4.2
Volatile Matter (%)	82	93
pH	5.4 – 7.4	5.5 – 6.1
Particle Size	<2 μm	<2 μm
Temperature (°C)	23 - 29	23 - 29

During the biogas generation process, the pH of the digester increased and decreased at certain periods during the retention period. The biogas generation rate rose with the retention period as the pH began to rise. Higher metabolic activity within the microorganisms present in the digester might explain the increasing biogas output with increased pHs.

3.2 MICROBIAL EXAMINATION OF COW DUNG

The microbial population of cow dung in the bioreactor is shown in Table 1 and is quantified in colony-forming units per millilitre (cfu/ml). The microbial population of the reactor was determined at the point of charging, flammability, the peak of production, and the end of the retention time. There was a large population of bacteria between the charging point and the point of flammability. This might be due to the presence of other bacteria, such as aerobic and pathogenic bacteria, which are present early in the digestive process.

Table 2. Microbial Examination

Microbiological Examination	Cow Dung
Total Bacterial Count (cfc/ml)	0.09 cfn
Total Coliform (mpn/100ml)	0.08 cfn
E coli (mpn/100)	0.07 cfn
Methanogen	Nil
Fungi	0.2 cfn

3.3 METHANE PRODUCTION

The weight of methane was taken twice for each day at 8 am and 5 pm and then vice-versa for the next day until the end of the retention period. It was noticed that the inside temperature of the digester was affected by the atmospheric condition (temperature and direct contact of sunlight with the digester). The daily production of gas achieved between 8 am and 5 pm during the retention time is shown in Table 2.

Table 2: Daily Records of Slurry in the Digester

Days	Weight of Gas(g) (8am-5pm)	pH (8am-5pm)	Temperature (°C) (8am – 5pm)
1	0.00-0.00	5.2	0
2	0.00-0.00	5.3	1
3	0.00-1.00	5.4	2
4	1.10-1.30	5.1	4
5	4.20-4.80	5.1	4
6	9.80-11.70	5.3	5
7	12.4-12.6	5.3	10
8	14.3-16.7	5.3	12
9	18.3-18.7	5.0	15
10	17.6-17.5	4.9	16
11	17.7-17.9	4.0	20
12	17.9-18.2	4.6	21
13	18.3-18.6	4.7	21
14	18.6-18.6	4.8	22
15	18.7-18.7	5.1	23
16	19.6-19.7	5.1	24
17	19.8-20.1	5.1	25
18	20.1-20.3	5.3	27
19	20.2-20.4	5.3	30
20	20.7-20.9	5.3	37

Figure 2 depicts the total biogas generated by the digester throughout the 20 days retention time. For the first two days of fermentation, there was no output in the digester, which might be explained by the inoculum being in the lag phase or methanogens undergoing a metamorphic development process by eating methane precursors created from the early activity, as stated by (Lima et al., 2018).

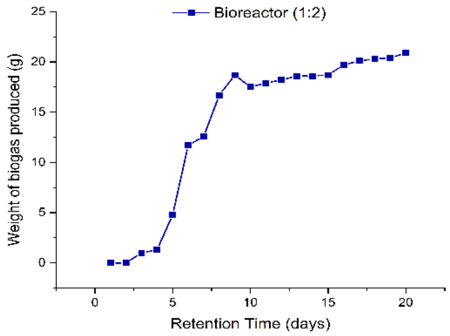

Fig. 2: The quantity of biogas produced daily in the bioreactor

The digester began producing biogas on the third day, with a continuous increase in output until the end of the 20-day retention period. This surge is due to an exponential growth in microorganisms, which increases fermentation rate and, as a result, biogas generation.

3.4 BIOGAS FLAMMABILITY

The onset of flammability occurred at varied times (from the time the digester was charged until the commencement of gas flammability). The early bacteria in the charged digester may have caused the initial burning of the gas. There may have been a larger release of free fatty acids when hydrolysis and acidogenesis began, making the environment inhospitable to the microorganisms that convert wastes to biogas, which are known to be pH sensitive and thrive best in the pH range of 6.5 to 8.0 (Stolze et al., 2015). The flammability of the gas improved and continued to increase long after the mixture in the digester nearly stopped production.

4 CONCLUSION AND RECOMMENDATION

The study found that sawdust, which is abundant everywhere, especially in the local environment, is an excellent biogas fuel. Because animal wastes are good starters for poor generating wastes, combining sawdust with cow dung resulted in continuous gas flammability throughout the digestion stage of the waste. The volume yield of biogas generation was shown to be affected by temperature change, pH, and Total Solid Concentration, among other parameters, in this study. Instead of being burned or dumped, these wastes (cow dung and sawdust) may be used to generate electricity, which is better for the environment.

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