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Biogas Production from Cow Dung and Pineapple Waste: A Sustainable Approach to Renewable Energy and Waste Management

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Abstract: Biogas production is a sustainable and renewable alternative energy source that offers a viable solution to reducing reliance on fossil fuels while addressing waste management challenges. Over recent years, biogas has gained significant acceptance due to its environmental benefits and potential for energy generation. This project focuses on the production of biogas using cow dung and pineapple waste as feedstock. A total of 5kg each of cow dung and pineapple waste were prepared and mixed with an equal volume of water to form a homogenous slurry. The mixture was loaded into a bio-digester fabricated within the department and allowed ferment anaerobically for 20 days under controlled conditions at an ambient temperature of 27°C. The biogas produced was analyzed using Gas Chromatography (GC), revealing a methane content of 80.44% and carbon dioxide content of 19.56%. The high methane concentration demonstrates the effectiveness of cow dung and pineapple waste as suitable substrates for biogas production. This study highlights the potential for utilizing agricultural and organic waste to generate clean energy, providing a sustainable method of handling waste management and energy sustainability. Further optimization of variables like temperature, retention duration, and substrate ratios could enhance biogas yield, paving the way for scalable applications in rural and urban settings.

Keywords: Biogas, Cowdung, Pineapple waste, Digester, Anaerobic

1. INTRODUCTION

The natural process of anaerobic digestion (without oxygen) produces biogas, a clean, sustainable, and cost-effective energy source. Biogas is a gas mostly made up of carbon dioxide and methane (60%) that is produced when anaerobic bacteria break down organic waste [1]. Methane (CH4), carbon dioxide (COz), and a few trace gases such water vapor, hydrogen sulfide (H25), nitrogen, hydrogen, and oxygen make up biogas. Because of its impurities, biogas is a sour gas that produces an acidic combustion product [2]. Traditional biomass, primarily used for heating, accounted for over 19% of the world's ultimate energy consumption in 2008, with hydroelectricity accounting for 3.2% [3]. Stated differently, agricultural and animal waste provide a high ratio of biogas, and their use is crucial for both economic and environmental aspect processing appropriate climate and environment condition [4]. In addition to being used in gas engines to transform gas energy into heat and electricity, biogas can be used for any heating application, including cooking [5]. Bio-methane can be produced from biogas by upgrading it to natural gas standards, because biogas is continuously produced, it is seen as a renewable resource, and it generates no net carbon dioxide [6]. Biogas is made up of the following compounds and percentages which are: methane (CH4) 50-70%, Carbon dioxide (COz) 20-25%, Nitrogen (N) 0-10%, Hydrogen (H) 0-1%, Hydrogen sulphide (H25) 0.1-0.5%., biochemical activities that take place under Anaerobic condition with cow dung and poultry waste which is readily available and its waste cause environment pollution, however the waste is capable of being transformed into a renewable power source, hence Anaerobic digestion processes is vital in the converting of the waste into a renewable source of energy [7]. Planning, constructing, and running biogas plants require an understanding of the basic methane fermentation process. Three distinct bacterial populations are involved in anaerobic fermentation. Biogas microbes consist of a broad category of intricate and diverse microbial organisms, particularly those that produce methane [8]. Three phases are involved in the manufacture of biogas: Hydrolysis, Acidogenesis, and fermentation also called methanogenesis. Long-chain compounds like protein, carbohydrates, and fat polymers are hydrolyzed to produce monomers, or tiny molecules. The breakdown is catalyzed by a number of distinct enzymes produced by various specialized bacteria, and the process is extracellular, meaning it occurs outside the bacterial cell in the surrounding liquid [9]. Digester is an airtight container, which can be constructed from tins, drums, glass or plastics containers depending on the scales and the means of the user, as the biodegradable feedstock enter into the digester depending on the digester type, it is heated to 35°C or higher after being combined with the contents [10] [11]. Anaerobic bacteria grow and consume the volatile substances in the feed stocks at this temperature. Biogas is a byproduct of this feeding. Since anaerobic microorganisms are poisoned by oxygen, the digester must be oxygen-free. The gas is collected in the piping system after rising above the feedstock on top of the digester during production. The digester, which is as well as a by-product can be used on soil as fertilizer to increase soil moisture retention and improve fertility [12]. In the batch process, organic waste to be digested is loaded into the container after which it is sealed, the waste is allowed to ferment after which it is removed, and a new batch of waste is loaded into the digester and the process is repeated. Alessandro Volta discovered methane in marsh gas in 1776, and anaerobic digestion - often referred to as anaerobic activities - occurs naturally in some soils and in sediments found in lakes and oceanic basins [13]. In the first step of digestion, bacteria hydrolyze the input materials, breaking down insoluble organic polymers like carbohydrates into soluble derivatives that other bacteria can use. The sugars and amino acids are subsequently transformed into carbon dioxide, hydrogen, ammonia, and organic acids by acidogenesis bacteria. Together with extra ammonia, hydrogen, and carbon dioxide, these bacteria convert the resultant organic acid into acetic acid. Ultimately, these compounds are transformed into carbon dioxide and methane by methanogen. Anaerobic wastewater treatment relies heavily on methanogenic archaea communities [14]. Several research has been done on biogas production using plant and animal generated waste, as in the study carried out by [15] which aims to adjust the substrate ratio and improve system stability by contrasting the anaerobic co-digestion of pineapple waste and cow manure with mono digestion under mesophilic conditions. The volatile solid (VS) contents of five distinct cow dung to pineapple waste ratios (1:1, 1:2, 1:3, 2:1, and 3:1) were evaluated. At a ratio of 1:3, the largest yields of biogas and methane were achieved, with 179.08 mL gas/g VS and 142.89 mL CH_4/g VS, respectively. Also, the ideal conditions for subcritical water pre-treatment were found to be 128.52°C for 5 minutes with a water-to-solid ratio of 5.67 to 1 after 20 pre-treatment runs were conducted by [16] at various temperatures, reaction durations, and water-to-solid ratios. Methane yield rose from 59.09 to 85.05 mL CH_4/g VS under these circumstances, with a 23% increase in biogas generation and a 44% increase in methane yield from the untreated. At temperatures exceeding 200°C, the yield of biogas decreased for all pre-treatments. [17] Investigated how methane yields at a variable substrate ratio are affected by the total solid. Three different total solids (12%, 20%, and 28%) and three different substrate ratios (cow dung to pineapple waste, or CD: PW) (1:1, 1:2, and 1:3) were used in the batch study. The maximum cumulative biogas production, 313 ml, was achieved with daily biogas collection for 28% total solid at a 1:1 ratio. This was followed by 28% total solid at a 1:3 ratio, which produced 246 ml of biogas yield. At 12% total solid, a 1:2 ratio produced the maximum methane yield (17.19 CH_4/g VS). The findings indicated that, when compared to other total solid percentages, the maximum methane yield is produced at 12% total solid at all ratios. Additionally, methane output dropped as the overall solid percentage grew from 12% to 28%. The numerical optimization results of the research carried out by [18] showed that setting the temperature to 30 °C, the pH to 6.0, and the pineapple mixing ratio to 62.5% produced the highest biogas yield of 1.98 m^3. Additionally, two and three times as much biogas were created overall when jack fruit waste, pineapple peels, and banana peels were co-digested with 25% cow dung, respectively. But only 50% of cow dung exhibited a substantial ($p < 0.05$) twofold improvement in jack fruit waste [19].

In the study carried out by [20], 50 kg prototype digesters with the labels A through C were charged with different mixtures of pig manure and pineapple peels. Only pineapple peels and pig manure were sent to digesters D and E, respectively. For 35 days, the wastes were mesophilically digested at a temperature between 25 and 37°C. The yield of biogas gradually increased as the blend of pig manure increased. For pig dung and pineapple peel mixes, as well as for pineapple peels alone, the onset of gas flammability was noted on the fifth day; however, for pig dung alone, it was noted on the sixth day. This occurred as a result of pineapple peel mixes having lower nitrogen concentrations than pig dung alone, which promotes an early flammability beginning. Between 65 and 71% CH_4, 28 and 34% CO_2, and trace amounts of hydrogen sulfide and carbon (II) oxide were all present in the biogas produced from the mixture. It was also discovered by [21] that the optimal combination of biogas slurry with high manorial content for phosphate solubilizers consisted of cow dung and fruit waste in a 1:2 ratio, characterized by elevated magnesium levels (0.0037%). This combination also exhibited notable levels of nitrogen (0.075 N) and phosphorus (0.00054% P), making it suitable for biometric observations in plant growth studies. A separate experiment conducted by [22] revealed that the mixture of pineapple peels, banana peels, and cow dung yielded significantly more biogas

(1.4 kg) compared to the combination of watermelon peels, orange peels, and cow dung (1 kg). These findings highlight the effectiveness of digested fruit waste as a substrate and cow dung as a co-digester in biogas production. [23] discovered that pineapple waste contains protease enzyme, making it an ideal raw material for bromelain production. Furthermore, the high cellulose content in pineapple waste has the potential to produce cellulose nanocrystals, biodegradable packaging, and bio-adsorbents, which can be applied in various industries such as polymer, food, and textile. Additionally, pineapple waste, particularly the peel, is suitable for producing wine, vinegar, and organic acids due to its high sugar content. The potential of pineapple waste for bioenergy production through biofuels (bioethanol, biobutanol, and biodiesel) and biogas (biomethane and biohydrogen) was also explored. A study by [24] investigated the effects of pH and temperature on the anaerobic digestion process of various agricultural wastes during biogas production. The study consisted of two phases: (1) using a single substrate (cow dung, cassava peels, yam peels, or pineapple peels) and (2) co-digesting the substrates with cow dung. The gas composition produced by each substrate and their mixtures was determined. The feedstock consisted of a 1:1 mixture of substrate and water, while co-digestion involved a 1:1:2 ratio of substrate, cow dung, and water. The results showed that co-digestion of cow dung and cassava peels yielded the highest biogas production with a methane content of 65.3%, followed by cow dung only (63.4%), co-digestion of cow dung and yam peels (51.4%), cassava peels only (46.2%), yam peels only (42.3%), and pineapple peels (0.0%). The results obtained by [25] showed that thermal pretreatment of pineapple peel waste was found to accelerate biogas production and reduce the lag phase in anaerobic digestion. The highest biogas yield (616.33 mL or 357.190 mL/g volatile solids) was achieved with pineapple peel waste pretreated for 25 minutes at 60 °C. In contrast, untreated pineapple peel waste produced significantly less biogas (384.33 mL or 219.619 mL/g volatile solids). Research by [26] revealed significant variations in biogas yield and methane content among different substrates. Biodegradability, substrate quality, and retention time were identified as key factors influencing biogas production. Notably, maize husk produced the highest volume of biogas and methane, with a 23.33 mL increase in biogas yield and 61.78% methane content over a 10-day hydraulic retention time. A study by [27] found that biogas production varied significantly among different substrates. Substrates with lower polysaccharide content (e.g., cellulose) and higher microbial populations produced more biogas than those with higher polysaccharide content and lower microbial populations.

2. MATERIALS AND METHOD

A 20-litre container was selected and marked at both the top and side to match the diameter of a ¾-inch PVC pipe. A soldering iron was used to bore a hole of the corresponding diameter, and the PVC pipe was inserted into the hole, ensuring a tight and secure fit. Measurements were taken and marks made at the hose's connection point to the container's neck, noting its diameter, and another hole was created using the soldering iron. The hose was inserted into this hole, and glue mixed with soil (sand) was applied around the pipe and hose interfaces to ensure an airtight seal, preventing any air leakage or entry. The container was painted black to prevent light penetration, which could support algae growth and hinder bacterial activity essential for biogas production. The hose was then connected to a T-connector valve system. One outlet of the T-connector was attached to a tyre tube for gas storage, another outlet was connected to the container (acting as the digester), and the third outlet was fitted with a regulatory valve to control gas flow. All openings and components were thoroughly sealed to ensure no air could escape or enter the digester. This assembly ensures an airtight system, facilitating efficient biogas production within the bio-digester. The materials of digester construction are ¾ PVC pipe, clips, hose, tyre tube, Glue, T-valve, Soldering iron, Paint (black), Brush, and Check valve. The raw materials for construction are Cow dung and Pineapple peel.

2.1 Procedure/preparation of sample

Fresh cow dung was obtained from Abataur, Osubi Road, in Warri, Delta State. Stones and foreign material were removed from the cow dung, and it weighed 5kg. The pineapple peel was diced into smaller pieces to enable it to penetrate through the funnel into the digester, and the pineapple waste weighed 5kg. Cow dung and pineapple peel will be mixed with water and will be stirred for 10 minutes to achieve an even mix. The mixed slurry (cow dung and pineapple peel) was loaded into the digester, and its cap was wholly sealed to ensure airtight. The digester was shaken twice daily to free trapped gases, even continuous mixing and prevention of scum accumulation at the surface of the slurry; the room temperature was 27°c then the digester was placed in the lab and was kept for 25days, and the gas was stored in the tyre-tube tested for methane.

3. RESULT AND DISCUSSION

The results obtained after the analysis are shown in Table 1.

Table 1: Table of Result

S/N	Sample ID	Detector	% Carbon dioxide	% Methane
1	Biogas	FID	–	100
2	Biogas	TCD	19.56	80.44

The table above shows the result obtained after the analysis of biogas using gas chromatography. From the table the following observation can be drawn.

3.1 Gas Chromatography Result

From the analysis of the makeup of the generated biogas, methane (CH4) is the only component in the FID detector while in the TCD detector, the composition was methane (CH) and carbon-dioxide (COz) only, methane is the major component with about 80.44% and carbon-dioxide composition of 19.56%.

3.2 Flame Ionization Detector (FID)

The Flame Ionization Detector (FID) is a scientific instrument utilized to quantify analytes in gas streams, commonly employed as a detector in gas chromatography. FID measurements are typically expressed in terms of methane equivalents, indicating the quantity of methane that would elicit the same response. Hydrocarbons generally exhibit molar response factors equivalent to the number of carbon atoms in their molecular structure. In contrast, oxygenates and other species containing heteroatoms tend to display lower response factors. Notably, carbon monoxide and carbon dioxide are not detectable by FID.

3.3 Thermal conductivity detector (TCD)

In gas chromatography, the thermal conductivity detector (TCD), sometimes referred to as a kartharometer, is a chemical-specific bulk property detector that is frequently employed. TCD is able to detect hydrocarbon and non-hydrocarbon components.

4. CONCLUSION

Based on the result obtained it may be said that biogas can be gotten from cow-dung and pineapple waste. The analysis carried out indicated that the biogas produced has the major constituent as methane, while carbon-dioxide was the remaining composition. The composition of methane was 80.44% and carbon-dioxide 19.56%.

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