*IOSR Journal of Biotechnology and Biochemistry (IOSR-JBB)*
*ISSN: 2455-264X, Volume 10, Issue 2 Series 1 (Mar. – Apr. 2024), PP 18-21*
*www.iosrjournals.org*

# Assessing The Anaerobic Methane Test Potential Of Various Feedstocks

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***Abstract:***
***Background :*** *In light of diminishing traditional fossil fuels and the associated environmental, social, and health challenges, there is a growing global imperative to transition towards sustainable energy alternatives. This paper presents a comprehensive review of the potential of biogas production from organic waste as a key solution to address these pressing issues. We explore the significant role of biogas in mitigating traditional biomass dependence in rural areas of developing nations and the associated challenges.*
***Materials and Methods:*** *We employed the water displacement method to quantitatively analyze biogas production, assessing the efficacy of different feedstocks. Additionally, qualitative analysis using Gas Chromatography was conducted to characterize the composition of the biogas generated. Furthermore, total and volatile solid analyses of the feedstock were performed to elucidate their properties and their relationship to gas production.*
***Results****: The water displacement setup using a combination of cow dung and Napier grass yielded a significantly higher volume of biogas compared to the setup using cow dung alone, as evidenced by the complete displacement of water. This observation suggests that the inclusion of Napier grass as a feedstock enhances biogas production efficiency.Gas Chromatography (GC) analysis further supported these findings, revealing that approximately 70% of the biogas generated from the cow dung + Napier grass setup consisted of methane. This substantial methane content underscores the efficacy of Napier grass as a feedstock for biogas production, highlighting its potential to serve as a sustainable energy source.*
***Keywords:*** *Biogas production, Organic waste, Sustainable energy, Anaerobic digestion, Methane, Gas removal experiments.*

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Date of Submission: 21-03-2024 Date of Acceptance: 31-03-2024

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## I. Introduction

As traditional fossil fuels and coal-based energy sources diminish, global focus is shifting towards sustainable alternatives. Despite technological progress, an estimated 3 billion individuals residing in rural areas of developing nations persist in their dependence on traditional biomass burning for cooking purposes. This reliance poses considerable challenges across environmental, social, economic, and public health domains. Hence, guaranteeing access to clean and cost-effective renewable energy stands as a pivotal imperative for fostering sustainable development within these regions.(Surendra et al., 2014)

A substantial volume of household waste, alongside various biodegradable materials, is currently underutilized and often discarded. Biogas emerges as a promising solution for energy generation, characterized by minimal waste production and the capacity to yield significant energy in its gaseous form. Predominantly composed of methane (50–75%) and carbon dioxide (25–50%), biogas also encompasses minor proportions of hydrogen sulfide, hydrogen, ammonia (1–2%), as well as traces of oxygen and nitrogen. (Atelge et al., 2020).

Anaerobic co-digestion stands out as a highly promising auxiliary method for waste treatment due to its remarkable energy recovery capabilities. A bio-digester system is meticulously designed and implemented to facilitate the anaerobic co-digestion process, aiming to efficiently convert a combination of cow waste and crop residue into biogas. (Sidra et al., 2018). The anaerobic digestion process unfolds through four distinct steps. Initially, during hydrolysis, organic polymers such as polysaccharides, lipids, and proteins undergo conversion into simpler compounds including sugars, fatty acids, amino acids, alcohols, acids, and other monomeric entities, accompanied by the generation of hydrogen and carbon dioxide. Subsequently, in the acidogenesis phase, the hydrolysis products are further degraded into volatile fatty acids (VFA), alcohols, carbon dioxide, and hydrogen. The third stage, acetogenesis, involves the conversion of VFA into acetic acid, carbon dioxide, and hydrogen. Finally, methanogenic Archaea catalyze the production of methane and carbon dioxide during the last step, known as methanogenesis. (Sikora et al., 2017).To enhance the efficiency of methane production and ensure optimal utilization of absolute methane, experiments are devised to remove various gases such as carbon dioxide (CO2), ammonia (NH4), hydrogen sulfide (H2S), among others. These removal experiments aim to purify the biogas by eliminating impurities and non-methane components, thereby maximizing the methane content and improving the quality of the produced biogas.

## II. Materials And Methods

**Collection of Feedstock-**

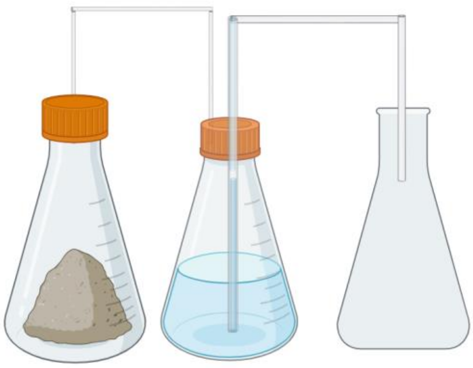
Cow dung samples were meticulously collected from Limbaaj Mata Mandir (Gaushala) located at coordinates 23.1526612 latitude and 72.6724215 longitude. The sampling process involved the utilization of sterile bottles, which were subjected to pretreatment by thorough washing with 70% ethanol. Following this, the bottles were rinsed with distilled water and subsequently dried in an hot air oven at 55$^{o}$ celsius to ensure sterility and prevent contamination during sample collection and storage. (Sylvia et al., 2016). The scooping and transfer of the cow dung samples were conducted using sterilized gloves and masks, adhering to strict protocols to minimize any potential points of contact between the samples and skin or other body parts, thus ensuring the integrity of the collected specimens. Additionally, to diversify the feedstock for biogas production, Napier grass was selected as a promising substitute due to its favourable characteristics and feasibility for methane production. Fresh Napier grass was collected in Sterile bags with gloves, from Limbaaj Maata Mandir.

**Water displacement Setup**

For the initial cow dung biogas test setup, three 1-liter Borosil flasks were utilized, serving as the control setup. In the first flask, anaerobic conditions were established to mimic a biogas digester environment. This was achieved by purging the flask with carbon dioxide. A quantity of 250 grams of cow dung was used as the feedstock, mixed with water in a ratio of 2:1. The prepared slurry was then introduced into the flask. A rubber cork with a single hole was securely sealed on the flask's opening. This hole accommodated a small tube, serving as the outlet for the biogas generated within the digester. The tube was connected to another 1-liter Borosil conical flask containing distilled water.The gas produced within the digester flask will flow into the second flask containing distilled water. According to Archimedes' principle of buoyancy, the volume of gas generated and purged from the digester will be equal to the volume of water displaced into the third flask. This third conical flask, left empty initially, serves to facilitate the collection and precise measurement of the displaced water, thereby enabling accurate quantification of the gas generated during the biogas production process.

A second water displacement setup was prepared where the feedstock was Cow dung and Napier grass. The ratio of Cow dung: Napier grass: Water was taken to be 1:2: 2. Napier grass was shred and cut to small pieces, as a physical pretreatment step.

**Fig no 1**: Model Water Displacement Setup



**A** **B** **C**

A: Feedstock Digester, B: Distilled Water, C: Displaced water Flask

**Feed Stock Characterization**

The feedstock plays a pivotal role in biogas production, as its characteristics can significantly influence both the quantity and quality of the produced biogas. Variations in feedstock composition, such as different ratios of organic matter, moisture content, nutrient availability, and chemical composition, can lead to fluctuations in biogas yield and purity. For instance, feedstocks rich in easily digestible organic materials, such as animal manure or food waste, typically result in higher biogas production rates compared to more lignocellulosic feedstocks like agricultural residues. Similarly, feedstocks with higher moisture content may promote better microbial activity and biogas production, while those with imbalanced nutrient compositions may require supplementation for optimal microbial growth and gas production. Therefore, understanding and optimizing the characteristics of the feedstock are crucial steps in maximizing biogas production efficiency and ensuring the purity of the generated biogas.

Total Solids (TS) and Volatile Solids (VS) were calculated according to (Epa & of Science, 2001). The total solid (TS) and volatile solid (VS) content significantly influence anaerobic digestion (AD). TS variations alter microbial community structure, affecting metabolic activities. Increased VS percentage correlates with greater biogas production, as VS represents organic matter available for microbial degradation. Managing TS and VS is crucial for optimizing AD efficiency and maximizing biogas yield. (Kelly Orhorhoro, 2017).

## III. Results And Discussion

Table no. 1 presents the total solids (TS) and volatile solids (VS) analysis of the two feedstock types. Given the higher volatile solids content in the Cow dung + Napier Grass setup, it is anticipated that biogas generation will also be higher compared to the cow dung setup.

**Table no. 1:** Shows TS and VS analysis of the two feedstocks.

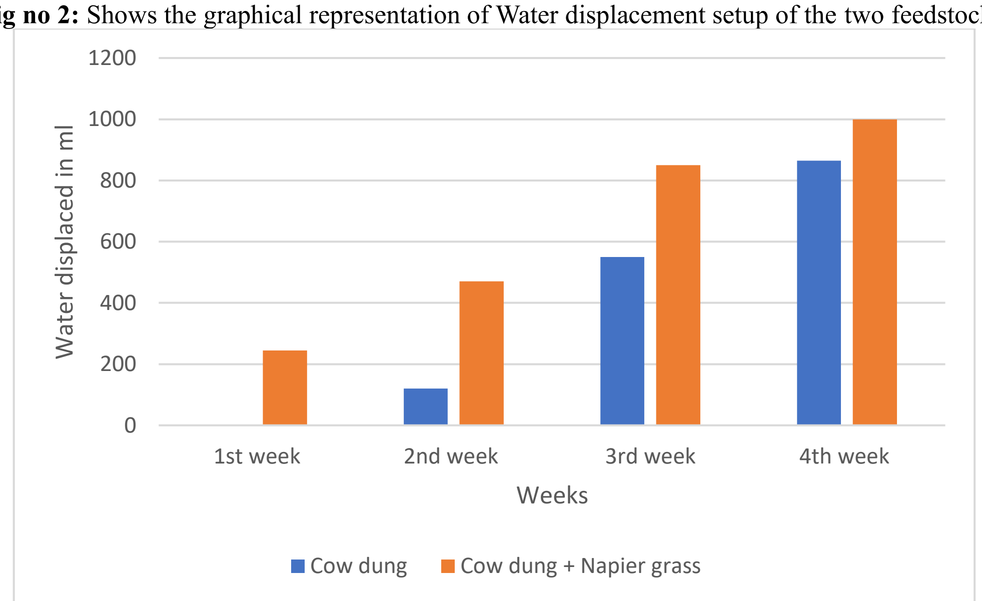
| Feedstock | TS | VS |
|---|---|---|
| Cow dung | 59.11% | 75.44% |
| Cow dung+ Napier grass | 52.07 % | 83.40% |

Weekly screenings of the third flak were conducted over a period of four weeks to analyse and measure the water displaced in both setups. This monitoring process enabled the quantification of the displaced water, providing data on the volume of gas generated and purged from the digester flask. By consistently tracking the displacement of water, any variations or trends in biogas production is observed and analysed over the course of the experimental period. This setup provides us with a quantitative estimate of the volume of gas generated from the feedstock setups in the conical flask.

**Table no 2:** Shows the water displaced from flask B to C in ml over a period of 4 weeks.

| Feedstock | 1st week | 2nd week | 3rd week | 4th week |
|---|---|---|---|---|
| Cow dung | 0 ml | 120 ml | 550 ml | 865ml |
| Cow dung + Napier grass | 245 ml | 470 ml | 850 ml | 1000ml |

**Fig no 2:** Shows the graphical representation of Water displacement setup of the two feedstocks.




Observations based on quantitative analysis indicate that combining cow dung with Napier grass as feedstock resulted in higher biogas yields. Napier grass, a tropical plant thriving in drought-prone regions, possesses substantial potential as a feedstock. With its composition comprising 30.9% total carbohydrates, 27% protein, 14.8% lipids, 18.2% total ash, and 9.1% fiber (dry weight), Napier grass constitutes an organic profile ideal for biogas production(Sawasdee & Pisutpaisal, 2014)..

For better estimation and understanding the nature of biogas generated, Gas Chromatography analysis (GC- Analysis) is done. GC Analysis, is an analytical technique for the separation and estimation of volatile substances in gaseous phase.

**Fig no 3**: Shows GC results of the biogas using Cow dung+ Napier Grass feedstock setup

Signal: TCD1B

| Time | Type | Area | Height | Width | Start | End |
|---|---|---|---|---|---|---|
| 3.192 | BV | 3325.330 | 817.504 | 0.062 | 3.101 | 3.257 |
| 3.272 | VB | 780.549 | 230.723 | 0.052 | 3.257 | 3.377 |
| 3.466 | BB | 1467.698 | 313.099 | 0.073 | 3.380 | 3.633 |
| 3.941 | BB | 46.814 | 7.438 | 0.097 | 3.834 | 4.119 |
| 4.471 | BB | 166.534 | 19.422 | 0.134 | 4.254 | 4.726 |
| 6.199 | BB | 137.393 | 9.352 | 0.217 | 5.757 | 6.529 |

| RetTime | Type | CalibPeakType | Signalname | Amount | Compound |
|---|---|---|---|---|---|
| 3.192 | Expected | Main | TCD1B | 11.671 | % N2 |
| 3.272 | Expected | Main | TCD1B | 70.335 | % METHANE |
| 3.466 | Unknown | NewMain | TCD1B | 0.000e+000 | % |
| 3.941 | Expected | Main | TCD1B | 2.701 | % CO2 |
| 4.471 | Expected | Main | TCD1B | 9.180 | % ETHANE |
| 6.199 | Expected | Main | TCD1B | 6.113 | % PROPANE |

The GC analysis gave a 70.335% of Methane ($CH_4$) and 2.701% of Carbon dioxide ($CO_2$). The water displacement setup acts as a $CO_2$ scrubbing unit, where distilled $H_2O + CO_2$ gives Carbonic water, which is a weak acid.

## IV. Conclusion

The choice of feedstock significantly influences both the quality and quantity of biogas produced in a digester plant. Utilizing Napier grass enhances biogas production, particularly yielding higher methane content. This holds promising potential for widespread energy production. Additionally, the residual feedstock slurry post-biogas generation serves as a nutrient-rich bio-based fertilizer, further augmenting the sustainability and circularity of the biogas production process.

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