COMPARATIVE EVALUATION OF BIOGAS PRODUCTION FROM COW DUNG, NEEM SEED AND GROUNDNUT SHELL

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ABSTRACT

Biogas, a renewable energy source primarily composed of methane and carbon dioxide, is produced by the microbial breakdown of organic materials in the absence of oxygen. This study investigates the production of biogas through the anaerobic digestion of organic substrates, specifically focusing on three substrate combinations Cow Dung alone, Cow Dung mixed with Neem seed, and Cow Dung mixed with Groundnut shell for maximizing biogas yield and to identify the optimal process parameters, such as temperature and pH, that enhance anaerobic digestion efficiency. The results of the experiments revealed that the combination of Cow Dung and Groundnut shell yielded the highest volume of biogas, producing 1.14 cm^3, compared to 0.84 cm^3 for the Cow Dung and Neem seed mixture, and 0.64 cm^3 for Cow Dung alone, respectively. The highest volume of biogas obtained from the combination of Cow Dung and Groundnut shell is attributed to the balanced Carbon-to-Nitrogen (C/N) ratio present in the Cow Dung and Groundnut shell combination, which is essential for supporting the growth of microorganisms responsible for breaking down organic matter efficiently during anaerobic digestion. the findings of the study revealed that the use of these materials can provide a promising solution for waste management and sustainable energy production.

Key words: *Biogas; Cow Dung; Neem seed; Groundnut shell; bio-digester; Waste Management.*

1. Introduction

Agricultural waste refers to the byproducts, residues, or unused materials generated during agricultural production, processing, and consumption activities (Abdul-Jabbar *et al.*, 2024). These *waste materials* can originate from various stages of the agricultural supply chain, including cultivation, harvesting, post-harvest handling, processing, and distribution (Ummalyma *et al.*, 2024). Agricultural waste can be classified into several categories based on its source, composition, and characteristics. Crop residues are the parts of crops left in the field after harvesting, such as stalks, leaves, husks, and stems. Crop residues can be generated from cereal crops (e.g., wheat straw, rice husks), oilseed crops (e.g., soybean hulls), and other agricultural commodities (Adesina *et al.*, 2024). Animal waste includes organic waste materials produced by livestock farming operations, such as manure, urine, and bedding materials (see Adesina *et al.*, 2024 for more). Animal waste contains valuable nutrients like nitrogen, phosphorus, and potassium, but it can also pose environmental challenges if not managed properly (Singhania *et al.*, 2024). Food processing by products are the residues generated during the processing of agricultural commodities into food, feed, or industrial products. Examples include fruit and vegetable peels, pulp, seeds, and trimmings from meat and poultry processing (Sindhu *et al.*, 2024). Agro-Industrial waste category encompasses waste materials generated by agricultural industries, "such as sawdust from lumber mills, bagasse from sugarcane processing, and spent grain from breweries" (Akpan *et al.*, 2022). Packaging waste materials used for agricultural products, including plastic bags, containers, crates, and packaging films, contribute to agricultural waste when disposed of improperly (Akpan *et al.*, 2022).

Biogas is a *renewable energy* source produced through the anaerobic digestion of organic materials such as agricultural waste, municipal solid waste, sewage sludge, and organic residues from industrial processes (Shukla *et al.*, 2023). This process involves microorganisms breaking down organic matter in the absence of oxygen, resulting in the production of biogas, primarily consisting of methane (CH_4) and carbon dioxide (CO_2), along with small amounts of other gases such as hydrogen sulfide (H_2S) and traces of water vapor (Babatunde *et al.*, 2022). *Biogas* production from agricultural waste represents a sustainable and eco-friendly solution for addressing energy needs while simultaneously managing organic residues. As the global demand for renewable energy continues to rise, optimizing the production of biogas from agricultural waste emerges as a crucial avenue for achieving both environmental and economic benefits. In 2016, Horváth and Kumar investigated that lignocellulose materials have been widely recognized for a considerable period of time as an alternative source of raw materials for the production of environmentally friendly biofuels. These materials possess the capability to be utilized in the production of solid fuels such as briquettes, liquid fuels like bioethanol, and gaseous fuels such as biogas (Devendra *et al.*, 2024). Extensive attention has been directed towards the utilization of agricultural residues, food waste, and energy crops to generate biofuels.

According to research on the biogas potential of eight aquatic weeds, salvinia and ceratopteris produced biogas with a maximum yield of 0.2 m3 kg-1. Subsequently, adding inoculums will keep pistia producing biogas for ten days (Hassan *et al.*, 2022). The largest amount of *methane* was produced when Borja *et al*. investigated the kinetics behavior of waste tires for the production of biogas supported by microorganisms in an anaerobic environment. Ferreira *et al.*, (2024) The process of producing biogas with wolffia and lemma revealed that these two microorganisms, when grown in a slurry fed digester containing *Cow Dung*, can be employed in conjunction with the manure to produce biogas (Gummert *et al.*, 2020). Investigations into the dynamics of producing biogas from municipal waste under various circumstances revealed encouraging results. Industries that process milk can use waste water to produce biogas and bio-hydration (Hamadou *et al.*, 2020). There have also been reports on the impact of pH, carbon to nitrogen ratio, and solid content on biogas production. A study was conducted to identify unique annual and perennial plants for the generation of biogas, and the results showed that the biogas produced was of a higher caliber (Perveen, 2024). The goal of this study is to maximize biogas yield under ideal operating conditions and to investigate the impact of producing biogas at a consistent, profitable, and effective rate utilizing rice husk and sugarcane pulp (Honcharuk *et al.*, 2024).

The study of production of biogas from agricultural waste is important for several reasons, encompassing environmental, economic, and energy-related considerations (Karthik *et al.*, 2024). Production of biogas derived from agricultural waste has the potential to make a significant contribution to our collective knowledge in a multitude of ways. First and foremost, such research can greatly enhance our understanding of renewable energy production (Khalil, 2020). By exploring the complexities of the biogas production procedure, specifically in relation to agricultural waste, we have the opportunity to expand our understanding in the realm of sustainable energy (Kusmiyati *et al.*, 2023). Biogas, which is mostly composed of methane, represents a green and enduring energy source. Through additional investigation in this area, I am able to cultivate more effective and economical techniques for utilizing renewable energy.

Materials and Method

Materials Used in the Study

The materials used in this research are:

1. Cow Dung (CD)
2. Neem Seeds (NS)
3. Groundnut Shells (GS)
4. Water
5. 3 bio digesters
6. pH meter
7. Thermometer
8. Beakers
9. measuring cylinder
10. water container
11. Beam balance

Method

Three bio digesters are made and labelled as bio-digester A, bio-digester B, and bio-digester C, for Cow Dung, Cow Dung with Neem seed and Cow Dung with Groundnut shells respectively.

Plate 1: Pictorial Representation of the Three Bio-Digester Sets

Digester A (Cow Dung)

Substrate Collection and Treatment

Fresh Cow Dung was collected from cattle farms. 4 kg of the Cow Dung was mixed with 1000 cm^3 (1 liter) water to form a slurry. Larger particles of Cow Dung were chopped to increase surface area and facilitate microbial action during digestion. A 0.03g of yeast was added as catalyst.

The Cow Dung slurry was fed into an anaerobic digester, which is a sealed tank where anaerobic bacteria decomposed the organic matter. The digester was maintained at a controlled temperature (mesophilic range of 30-40°C) to optimize microbial activity. The pH was measured as 7.12

Plate 2: Bio-Digester A Set Up

Retention Time

Retention time is the length of time that the substrate spends in the digester. The substrate remains in the bio digester for 7 days then the subsequent measurement of the pH level, temperature and biogas produced were recorded for 5 consecutive days.

Determination of Biogas Produced

The amount of biogas produced was determined using water displacement method. The water displacement method is a technique used to measure the volume of a substance by measuring the volume of water it displaces.

Plate 3: Bio-Digester A Water Displacement Method

A measuring cylinder was filled with water and then put upside-down in a container containing water in it. A retort stand was used to hold the measuring cylinder. The gas hose from the bio digester was inserted in the measuring cylinder and the initial water level in the cylinder was recorded.

The biogas was then allowed to flow from the bio digester to the cylinder and since gas is less dense than water, the biogas accumulated the top of the cylinder causing decrease in water level. The new water level was recorded and the volume of the gas produced was calculated by subtracting the new water level from the initial water level. This method is based on Archimedes' principle, which states that "the volume of an object is equal to the volume of the fluid it displaces. A thermometer was used to determine the temperature.

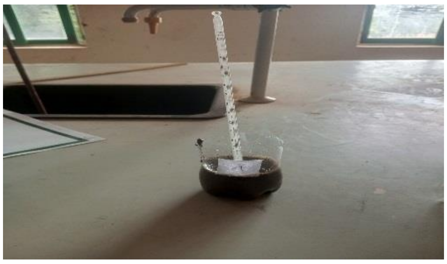

Plate 4: Determination of Bio-Digester A Temperature

Digester B (Cow Dung and Neem Seed)

Substrate Collection and Treatment

Fresh Cow Dung was collected from cattle farms. 4 kg of the Cow Dung was mixed with 1000 cm^3 (1 liter) water to form a slurry. Larger particles of Cow Dung were chopped to increase surface area and facilitate microbial action during digestion.

Neem seeds were dried and pounded then 1 kg of the powder was used. A 0.03g of yeast was added as catalyst. The slurry was fed into an anaerobic digester, which is a sealed tank where anaerobic bacteria decomposed the organic matter. The digester was maintained at a controlled temperature (mesophilic range of 30-40°C) to optimize microbial activity. The pH was measured as 6.20

Plate 5: Bio-Digester B Set Up

Retention Time

The substrate remains in the bio digester for 7 days then the subsequent measurement of the pH level, temperature and biogas produced were recorded for 5 consecutive days.

Determination of Biogas Produced

The amount of biogas produced was determined using water displacement method. A measuring cylinder was filled with water and then put upside-down in a container containing water in it. A retort stand was used to hold the measuring cylinder. The gas hose from the bio digester was inserted in the measuring cylinder and the initial water level in the cylinder was recorded.

Plate 6: Bio-Digester B Water Displacement Method

The biogas was then allowed to flow from the bio digester to the cylinder and since gas is less dense than water, the biogas accumulated the top of the cylinder causing decrease in water level. The new water level was recorded and the volume of the gas produced was calculated by subtracting the new water level from the initial water level. A thermometer was used to determine the temperature.

Plate 7: Determination of Bio-Digester B Temperature

Digester C (Cow Dung and Groundnut Shell)

Substrate Collection and Treatment

Fresh Cow Dung was collected from cattle farms. 4 kg of the Cow Dung was mixed with 1000 cm^3 (1 liter) water to form a slurry. Larger particles of Cow Dung were chopped to increase surface area and facilitate microbial action during digestion.

Groundnut shells were dried and pounded then 1 kg of the powder was used. A 0.03g of yeast was added as catalyst. The Cow Dung and Groundnut shells was thoroughly mixed to create a homogeneous mixture. This ensures even distribution of nutrients and enhances microbial access to substrates during digestion. The mixed slurry was transferred into an anaerobic digester. The digester was maintained at a controlled temperature of mesophilic temperatures (30-40°C) to optimize microbial activity. The pH was measured as 6.1. Anaerobic bacteria decomposed the organic materials in the Cow Dung and Groundnut shells, producing biogas as a metabolic byproduct.

Plate 8: Bio-Digester C Set Up

Retention Time

The substrate remains in the bio digester for 7 days then the subsequent measurement of the pH level, temperature and biogas produced were recorded for 5 consecutive days.

Determination of Biogas Produced

The amount of biogas produced was determined using water displacement method. A measuring cylinder was filled with water and then put upside-down in a container containing water in it. A retort stand was used to hold the measuring cylinder. The gas hose from the bio digester was inserted in the measuring cylinder and the initial water level in the cylinder was recorded. The biogas was then allowed to flow from the bio digester to the cylinder and since gas is less dense than water, the biogas accumulated the top of the cylinder causing decrease in water level.

Plate 9: Bio-Digester C Water Displacement Method

The new water level was recorded and the volume of the gas produced was calculated by subtracting the new water level from the initial water level. This method is based on Archimedes' principle, which states that "the volume of an object is equal to the volume of the fluid it displaces. A thermometer was used to determine the temperature.

Plate 10: Determination of bio-digester C temperature

Results and Discussion

At the end of this research, biogas was obtained from Cow Dung, Cow Dung with Neem seed and Cow Dung with Groundnut shell. The experimental results obtained were tabulated in table 1- 3 of this chapter.

Bio Digester A (Cow Dung)

Mass of Cow Dung: 04 kg
Volume of water used: 1000 cm^3
Mass of bio digester (before adding substrate): 01 kg
Mass of bio digester (after adding substrate): 06 kg
Amount of yeast added: 0.03 kg
Temperature: 31 ^oc
pH level: 7.12
Retention time: 7 days

TABLE 1: Bio-Digester A Measurements (Cow Dung)

S/N	Days	pH level	Temperature (^oc)	Biogas produced (cm^3)	M_1 (kg)	M_2 (kg)
1	Day 1	7.08	32.2	0.5	6.50	6.00
2	Day 2	7.03	33.1	0.6	6.50	6.02
3	Day 3	6.98	34.1	0.6	6.60	6.00
4	Day 4	6.94	34.9	0.7	6.70	6.00
5	Day 5	6.90	35.6	0.8	6.80	6.00

Where M_1 = mass of bio digester before measuring biogas
M_2 = mass of bio digester after measuring biogas

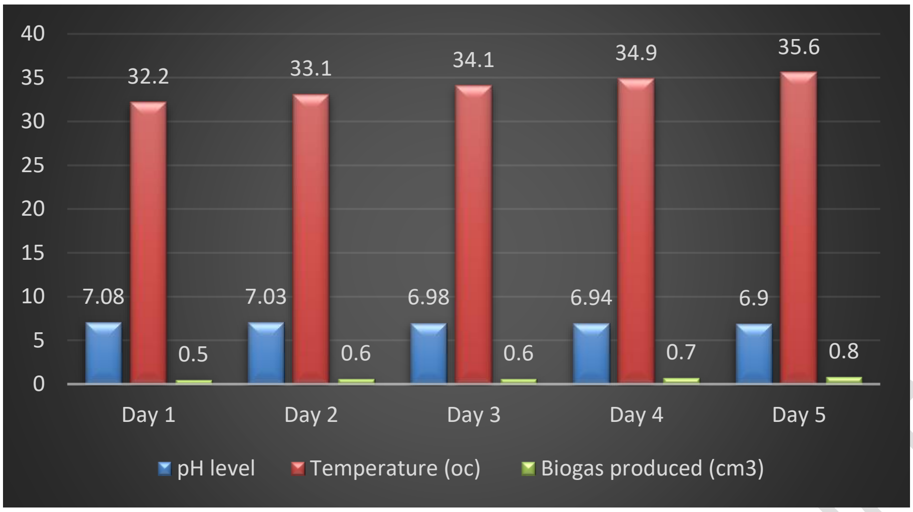

Figure 1: Graphical Representation of Bio-Digester A (Cow Dung)

Bio Digester B (Cow Dung and Neem Seed)
Mass of Cow Dung: 04 kg
Mass of Neem seed: 01 kg
Volume of water used: 1000 cm^3
Mass of bio digester (before adding substrate): 01 kg
Mass of bio digester (after adding substrate): 07 kg
Amount of yeast added: 0.03 kg
Temperature: 32 ^{o}c
pH level: 6.20
Retention time: 7 days

TABLE 2: Bio-Digester B Measurements (Cow Dung and Neem Seed)

S/N	Days	pH level	Temperature (^{o}C)	Biogas produced (cm^3)	M_1 (kg)	M_2 (kg)
1	Day 1	6.18	33.5	0.8	7.80	7.00
2	Day 2	6.15	34.8	0.7	7.70	7.00
3	Day 3	6.12	35.9	0.8	7.80	7.00
4	Day 4	6.09	36.5	0.9	7.90	7.00
5	Day 5	6.06	37.1	1.0	8.00	7.00

Where M_1 = mass of bio digester before measuring biogas
M_2 = mass of bio digester after measuring biogas

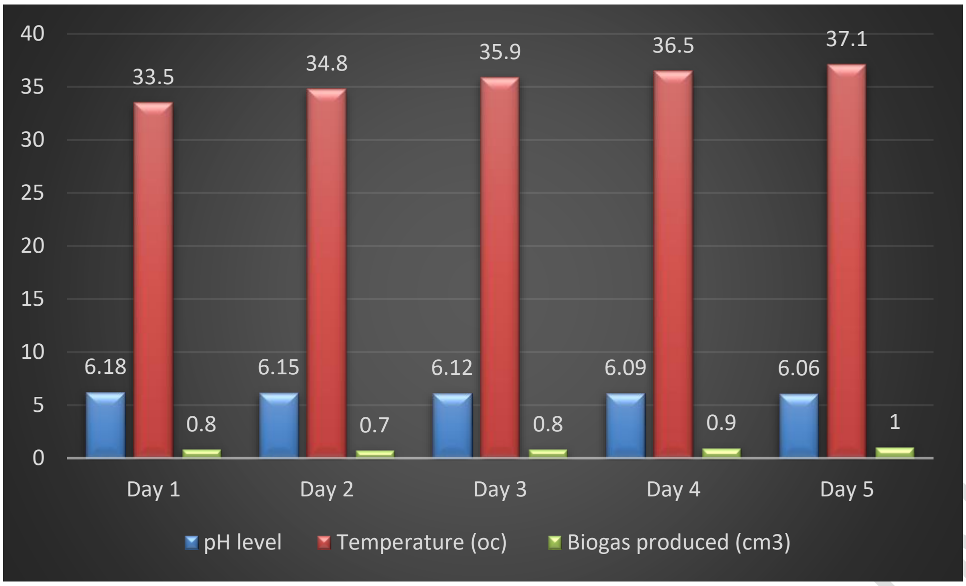

Figure 2: Graphical Representation of Bio-Digester B (Cow Dung and Neem Seeds)

Bio Digester C (Cow Dung and Groundnut Shell)
Mass of Cow Dung: 04 kg
Mass of Groundnut shell: 01 kg
Volume of water used: 1000 cm^3
Mass of bio digester (before adding substrate): 01 kg
Mass of bio digester (after adding substrate): 07 kg
Amount of yeast added: 0.03 kg
Temperature: 31 ^oc
pH level: 6.62
Retention time: 7 days

TABLE 3: Bio-Digester C Measurements (Cow Dung and Groundnut Shell)

S/N	Days	pH level	Temperature (^oc)	Biogas produced (cm^3)	M_1 (kg)	M_2 (kg)
1	Day 1	6.61	32.4	0.8	7.80	7.00
2	Day 2	6.59	33.7	1.0	8.00	7.00
3	Day 3	6.57	35.0	1.2	8.20	7.00
4	Day 4	6.51	36.1	1.3	8.30	7.00
5	Day 5	6.48	37.7	1.4	8.40	7.00

Where M_1 = mass of bio digester before measuring biogas
M_2 = mass of bio digester after measuring biogas

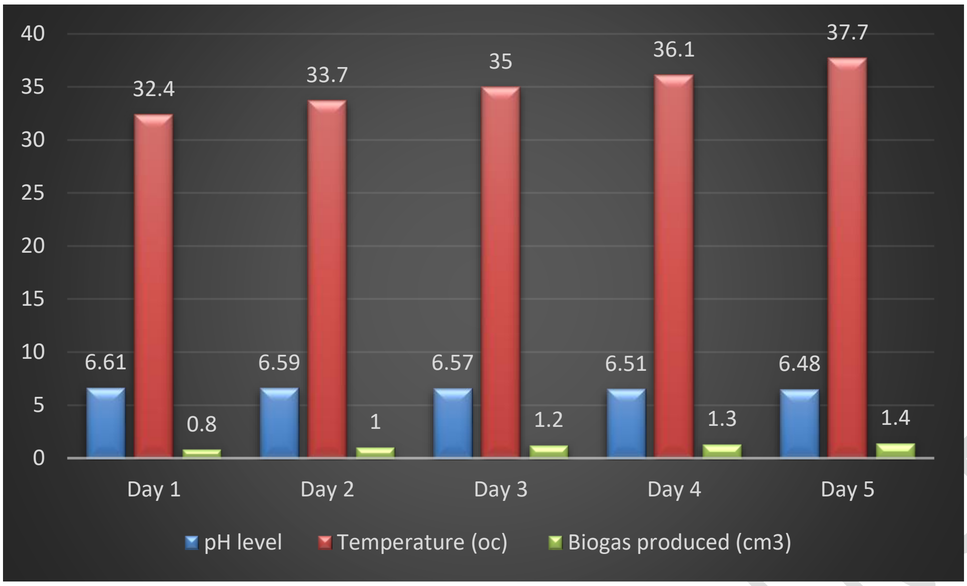

Figure 3: Graphical Representation of Bio-Digester C (Cow Dung and Groundnut Shells)

Discussion

The biogas volume produced shows an increasing trend over the days (from table 1), starting at 0.5 cm³ on Day 1 and reaching 0.8 cm³ by Day 5. This increase indicates that the microorganisms responsible for biogas production were becoming more active or efficient as the digestion process progressed. The gradual increased in biogas yield was be due to the microorganisms adapting to the conditions within the bio-digester over time, leading to improved digestion and gas production.

The pH values recorded are relatively stable across the days, ranging from 6.90 to 7.08. This suggests that the environment within the bio-digester remained within a neutral pH range, which is generally favorable for the anaerobic digestion process.

The temperature readings show slight variations, ranging from 32.1°C to 34.1°C. This temperature range aligns well with mesophilic conditions (20-40°C), which are common for biogas production. This is in similar to the result obtained in studies conducted by Adesina *et al.*, (2024), Akpan *et al.*, (2022) and Kusmiyati *et al.*, (2023) in their studies.

The mass measurements before and after measuring biogas (M_1 and M_2) indicate slight variations, but they are relatively consistent across the days. This minor change suggested that the substrate in the bio-digester is decomposing slowly, with a small amount of material being converted to biogas. The minimal decrease in mass aligns with the gradual increase in biogas production.

From table 2, the biogas volume shows a steady increase each day, beginning at 0.8 cm³ on Day 1 and reaching 1.0 cm³ by Day 5. This indicates that the microbial community is adapting to the environment and becoming more efficient in digesting the organic material and producing biogas. The steady increase suggests a healthy bio-digester environment, with microorganisms effectively decomposing the substrate to produce biogas over time.

The pH levels for Bio-digester B in table 2 shows a decrease slightly over the days, starting at 6.18 on Day 1 and reaching 6.06 by Day 5. This slight decrease indicates that the environment within the bio-digester may be becoming slightly more acidic over time. A pH below 7 is still within an acceptable range for biogas production, but if it continues to drop, it could hinder microbial activity. The gradual decrease might suggest microbial activity is producing acidic byproducts, which is normal in the initial stages of anaerobic digestion.

The temperature gradually increases over the days, starting from 33.5°C on Day 1 and reaching 37.1°C by Day 5. These temperatures are within the upper end of the mesophilic range, which is suitable for anaerobic digestion. The increase in temperature could stimulate microbial activity, potentially leading to higher biogas production. However, if the temperature continues to rise, it might lead to thermophilic conditions, which could alter microbial populations and affect biogas production rates.

The mass readings before and after measuring biogas (M_1 and M_2) show slight variations, with M_1 slightly increasing from 7.10 kg on Day 1 to 7.15 kg on Day 5, and M_2 showing a slight increase as well. These small changes indicate a consistent rate of substrate consumption, as only a small amount of material is converted to biogas each day. This aligns with the incremental increase in biogas volume observed. Bio-digester B is operating effectively, with favorable conditions that support increasing biogas yield.

From table 3, the biogas production increases from 0.8 cm^3 on Day 1 to 1.4 cm^3 on Day 5. This steady increase in biogas production suggests that the bio-digester is progressively stabilizing and may be reaching its optimal conditions for gas production.

The pH levels gradually decrease over the five days, starting from 6.61 on Day 1 and reaching 6.48 on Day 5. This trend may indicate an increase in acidity, which could affect the microbial activity inside the bio-digester.

The temperature increases daily, starting from 32.4°C on Day 1 and reaching 37.7°C on Day 5. Higher temperatures could enhance biogas production up to an optimal point, as microbial activity typically increases with temperature.

Table 3 includes two mass measurements, M_1 and M_2, where M_1 is the mass before measuring biogas and M_2 is the mass after. M_1 slightly increases over time, possibly indicating an accumulation of organic material or a reaction by-product. M_2, however, remains relatively stable, with minor fluctuations, suggesting a controlled environment in terms of mass loss or biogas extraction. This is in similar to the result obtained in studies conducted by (Babatunde *et al.,* 2022) (Chavan *et al.,* 2021), (San *et al.,* 2024) and (Hassan *et al.,* 2022) in their studies.

TABLE 4: Summary of All Results

S/N	Bio-digester	pH level	Temperature (^oC)	Biogas produced (cm^3)
1	A	5.79	35.56	0.64
2	B	6.12	33.98	0.84
3	C	6.55	34.98	1.14

Conclusion

This study investigates the feasibility of using *agricultural waste* to produce biogas, a renewable energy source. It primarily explores the potential of Cow Dung, Neem seed, and Groundnut shell as substrates for biogas production.

Table 4 summarizes key measurements from three different bio-digesters (A, B, and C) under specific conditions of pH, temperature, and biogas production.

Bio-digester A has the lowest pH level at 5.79, indicating more acidic conditions. Bio-digester B has a pH of 6.12, which is closer to neutral but still slightly acidic. Bio-digester C has the highest pH at 6.55, making it the least acidic among the three. Generally, microbial activity for biogas production performs better in near-neutral pH conditions, so Bio-digester C's pH could be advantageous.

Bio-digester A is at 35.56°C, B at 33.98°C, and C at 34.98°C. The temperatures are fairly close, within a few degrees of each other. However, bio-digester A has the highest temperature, which could be beneficial as increased temperatures (up to an optimal point) tend to enhance microbial activity and gas production.

Bio-digester A produces 0.64 cm³, B produces 0.84 cm³, and C produces 1.14 cm³. Bio-digester C has the highest biogas output, followed by B and then A. This trend suggests that Bio-digester C's combination of higher pH and near-optimal temperature may be more effective for gas production.

Bio-digester C performed best in terms of biogas output, likely due to its higher pH (closer to neutral) and a temperature that supports microbial activity. Bio-digester A, with the lowest pH and highest temperature, produces the least biogas, which may indicate that the acidity is inhibiting microbial efficiency despite the warm temperature. This is in similar to the result obtained in studies conducted by (Horváth *et al.,* 2016), (Rastogi *et al.,* 2021), and (Perveen, 2024) in their studies.

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