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Effect of Slurries and Substrate Combination Ratios on Biogas Production from Rice Husk and Cow Dung

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Abstract

This work studied the effect of varying ratios of substrates on biogas production from rice husk and cow dung and was carried out using different slurry concentration of 1:4 and 1:12 solid to water ratios and monitored over 48days. The results from daily production show that all the digesters started biogas production in day 1, with rice husk recording the highest biogas of (400 cm^3),while most of the digesters recorded their highest biogas production in the early days. It was observed that rice husk stopped production in day 29 and 38 with biogas yield of 10 cm^3 and 5 cm^3 respectively. The weekly biogas production for the digesters in 1:4 and 1:12 ratios shows that hydrolysis of rice husk takes place faster than cow dung, were rice husk produces the highest biogas of (2190 cm^3) in week 1 and rice husk plus cow dung with highest biogas yield of (580 cm^3) in week 4. It was also observed that only cow dung was producing biogas steadily at average temperature of 35 °C. The effect of slurry concentration on the substrates used shows that; less dilute slurry is better for biogas production, $D_1>D_4$ and $D_2>D_5$ for Rice husk and cow dung respectively, while for the combination of rice husk and cow dung shows the reverse case $D_6>D_3$. proximate analysis shows the % moisture content for rice husk(10 %), cow dung(15 %) and %Organic matter content for rice husk(5 %), cow dung (10 %), this indicate both samples can make a better substrate for biogas production with the trend cow dung > rice husk. From the search conducted, It may be concluded that slurry concentration play a vital role in biogas production than substrate combination ratios with less slurry concentration showing a promising trend for optimum biogas yield as sustainable energy sources.

Keywords: Biogas, Bio-fertilizer, Cow dung, Rice husk.

Introduction

The current sources of electricity in Nigeria are usually hydropower, oil, coal (for lightening, cooking, and running electrical appliances, inline with domestic activities that usually consume energy in most Nigerian households. Most of the people living in rural areas rely on crop residues, fire wood and charcoal for cooking because they couldn't afford the high cost of petroleum fuels (kerosene and LPG), while electricity is known to be unreliable [1]. Even in the urban areas where electricity, kerosene and LP[G are available to most of the households, the usage of the energy sources for domestic activities depends on the household income, with people often giving preference to low-cost energy sources [2]. However, the combustion of fossil fuel resources to meet these energy needs leaves a negative footprint. It contributes to global warming due to the emission of carbon dioxide (CO_2), methane

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(CH_4) and nitrous oxide (N_2O) all classified as greenhouse gases (GHGs). In addition, the depletion of fossil fuel resources due to its non-renewable nature and massive utilization has brought the need for an alternative energy source that is renewable, abundant and cost effective. Biogas production from locally available renewable organic resources can be a good alternative because it contributes to the reduction of greenhouse gases (GHGs) emissions. Biogas technology provides an attractive route for the utilization of different categories of biomass for meeting energy needs. This technology offer a unique set of benefits, some of which include good waste management technique, enhancement in the ecology of rural areas, decrease in pathogenic diseases, optimization of the energy consumption of rural communities and promotion in agricultural structure [3]

In biogas production, different factors are of great importance, however the type of organic substrate used has been found to play a significant role in the yield and composition of the biogas .A number of biogas digesters operating worldwide utilize different types of substrates and this results in a unique microbial community and variation in methane composition in such digesters. Some studies have used a sequencing technology to analyze the structure of these microorganism communities involved in the AD process. These microorganisms consisting of bacteria, fungi and archaea are responsible for all the reactions occurring within the digester system [3].

The variation in biogas compositions are dependent on the substrate types used, which is traceable to the difference in their chemical composition as well as their biodegradability. Biogas formation from various substrates reported in the literature will be investigated and their pros and cons will be addressed to enable the synthesis of knowledge for proper means of maximizing biogas yield from organic matters structure [3].

Chemical Composition of Biogas

Biogas is a mixture of gases comprising mostly of methane (CH_4) and carbon dioxide (CO_2) as well as a low quantity of other gases such as hydrogen sulphide (H_2S), ammonia (NH_3), oxygen (O_2), hydrogen (H_2), nitrogen (N_2) and carbon monoxide (CO), Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 °C to 750° C. It is an odourless after burning and colourless gas that burns with clear blue flame similar to that of liquefied Petroleum gas (LPG). Biogas is produced through the anaerobic digestion of organic materials such as agricultural residues, animal waste, sewage sludge, and organic household waste. This process involves the breakdown of organic matter by microorganisms in the absence of oxygen, resulting in the release of methane (CH_4) and carbon dioxide (CO_2) gases. Biogas production offers numerous economic, environmental, and social benefits, making it an attractive alternative to conventional fossil fuels [4].

Table 1: Chemical Composition of Biogas (%) Reported by **[5]**

Compound	Chemical Composition	Percentage (%) in Biogas
Methane	CH_4	50 – 75
Carbon (IV) Oxide	CO_2	25 – 50
Nitrogen	N_2	0 – 10
Hydrogen Sulphide	H_2S	0 – 3
Hydrogen	H_2	0 - 1
Oxygen	O_2	0 - 0.5

The composition and characteristics of the feedstock significantly influence biogas production efficiency. Substrates with high organic content, such as livestock manure and food waste, are ideal feedstock for biogas digestion due to their rich nutrient composition and high biodegradability. Additionally, the proper balance of carbon and nitrogen, as well as optimal process parameters such as temperature, pH, and hydraulic retention time, are essential for maximizing biogas yield and quality [6].

Variations in feedstock properties, such as lignocellulos content and moisture content, were demonstrated by [9], which can affect biogas yield and methane content. Biogas production from rice husks and cow dung offers potential environmental and economic benefits, including waste reduction, renewable energy generation, and carbon mitigation. However, the feasibility and sustainability of biogas projects depend on factors such as feedstock availability, processing costs, and market demand [7].

Rice hulls or husks are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice husks can be put to use as building material, fertilizer, insulation material, or fuel. Rice hulls are part of the chaff of the rice. They are composed of hard materials like silica and lignin, which protect the seed during the growing season. Rice husk ash, a byproduct of burning the husk, is rich in silica, which can be used in various industrial applications, including ceramics and construction materials. They can be used as a fertilizer or soil amendment. Rice husk and its byproducts are used in adsorbents, biofuels, and soil amendments [8].

Cow dung, also known as cow pats, cow pies or cow manure, is the waste product (faeces) of bovine animal species. These species include domestic cattle (cows), bison (buffalo), yak, and water buffalo. Cow dung is the undigested residue of plant matter which has passed through the animal's gut. The resultant fecal matter is rich in minerals. Color ranges from greenish to blackish, often darkening soon after exposure to air. Cow dung, which is usually a dark brown color, is often used as manure (agricultural fertilizer). If not recycled into the soil by species such as earthworms and dung beetles, cow dung can dry out and remain on the pasture, creating an area of grazing land which is unpalatable to livestock. In many parts of the developing world, and in the past in mountain regions of Europe, caked and dried cow dung is used as fuel. Dung may also be collected and used to produce biogas to generate electricity and heat. The gas is rich in methane and is used in rural areas of India and Pakistan and elsewhere to provide a renewable and stable (but unsustainable) source of electricity. In central Africa, Maasai villages have burned cow dung inside to repel mosquitos [9].

Materials & Methods

Materials

Biogas digesters (440g Peak milk tin), Thermometer, pH meter, Analytical weighing balance, Stirrer, 500cm^3 Measuring Cylinder, Retort stand, Biogas collection tube (diameter 0.5cm, length 1.5m), Araldite Glue, Water bulb, Drying Oven, Muffle furnance (Carbolite Gero 30-3000 °C, ELF 1100, ELF 11/14B United Kingdom), Mortar and pestle

Methodology

The methods used in carrying out this research includes: Description of the sampling site, Preparation of slurries, construction of digesters, gas collection jars and the procedures for conducting proximate analysis on the substrates

Sampling Site

This research was conducted at Azare Local Government area Bauchi State. Azare is the headquarter of Katagum local government area of Bauchi state, and bounded to the east by Damban local government and Potiskum, Yobe State and to the south by Misau Local Government, in the west by Jamaare Local Government, and to the north by Itas/Gadau Local Government area of Bauchi state. It’s located at 11º40’27”N 10º11’28”E at an elevation of 436 metres with estimated population of 69,035 which are mostly Hausa, Fulani and Kanuri [10].

Figure 1: Map of Azare town, Bauchi State (Extracted from Google Map)

Construction of Digesters

Six (6) cylindrical 440 g Peak Milk tins were used to construct the digesters that are labeled as D1 to D6.The tins were cleaned thoroughly and a hole was bored at the centre of the lid of each tin. A PVC rubber tube (diameter 0.5 cm, length 1.5 m) tube was inserted into the hole and glued using araldite [11].

Sample collection:

Rice Husk

Rice husk sample was collected at different locations from local rice mills within Azare metropolis, Bauchi State. The sample was washed, dried, powdered and later stored in separate black polythene bags for subsequent use. The random sampling was done in order to select the representative samples for biogas production and proximate analysis.

Cow dung

Cow dungs were collected from cattle sheds in Azare local government area of Bauchi State. Same procedure was followed as mentioned above for cow dung sample.

Slurry Preparations

Surry Preparation for Group A (1:4 solid to water)

The following digesters which were labeled as group (A) contain slurry preparations as follows:

i. In Digester one (D_1), 150g of rice husk was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives slurry of rice husk to water ratio of 1:4.

ii. In Digester two (D_2), 150 g of cow dung was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives slurry of cow dung to water ratio of 1:4.

iii. In Digester three (D_3), 75 g each for Rice husk and cow dung was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives slurry of Rice husk and cow dung to water ratio of 1:1:4.

Surry Preparation for Group B (1:12 solid to water)

The following digesters which were labeled as group (B) contain slurry preparations as follows:

A) In Digester four (D_4), 58 g of rice husk was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives slurry of rice husk to water ratio of 1:12.

B) In Digester five (D_5), 58 g of cow dung was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives cow dung to water ratio of 1:12.

C) In Digester six (D_6), 29 g each for Rice husk and cow dung was weighed and 600 cm^3 of water was added gradually with thorough stirring. The initial pH was recorded and the lid of the digester was put in place and sealed with Araldite to ensure air-tightness. This gives slurry of rice husk and cow dung to water ratio of 1:1:12.

Experimental Set-up for Production and Collection of Biogas

A plastic water trough which is large enough to accommodate six (6) cylindrical measuring cylinders (capacity, 500 cm^3) was filled with water. The cylinders were each filled with water and inverted into the water-filled trough and clamped to a retort stand. The unattached end of the rubber tube for each digester in group A and B was inserted into separate inverted cylinder to serve as the gas collection jar. The downward displacement of water in the cylinder was recorded as volume (cm^3) of biogas produced. The readings were recorded after each 12 hours interval for the period of 48days. And the laboratory temperature readings were noted daily over the same period and the average temperature for the laboratory were equally calculated [11]

Also, the initial pH for each digester immediately after slurry preparations and the final pH readings after they have been dislodged were equally recorded, and the average pH was calculated.

Determination of Moisture Content

The method of Association of Official Analytical Chemists [12] was adopted for the determination of moisture contents using hot air drying oven.

The crucible was washed and dried in an oven for 1hour, and then cooled in a desiccator and weighed (W_0). A given weight (W_1) of the sample (Rice husk and Cow dung) was placed in the crucible and dried in an oven at 105 -110 ºC for 24 hours. The crucible and its content were allowed to cool in the desiccator before weighing. Heating and cooling was repeated until a constant weight was obtained (W_2).

The percentage (%) moisture content was calculated using the formula:

$$\% \, Moisture = \frac{w_1 - w_2}{w_1 - w_0} \, x \, 100 \quad \text{--------Equation 1.0}$$

W_0 = Weight of empty crucible

W_1 = weight of crucible and sample before drying

W_2 = weight of crucible and sample after drying

Determination of Ash Content

The ash content was determined using [12] method. The crucible was washed, dried, cooled in a desiccator and weighed (W_0). About 2.0 g of the dry samples was placed in a crucible, weighed (W_1) and heated in a muffle furnace at 550 °C for three hours. The hot crucible and residue were cooled in a desiccator and weighed to constant weight (W_2). The percentage (%) ash content was calculated using the formula:

$$\% \, Ash = \frac{w_1 - w_2}{w_1 - w_0} \, x \, 100 \quad \text{---------------- Equation 2.0}$$

W_0 = Weight of empty crucible
W_1 = weight of crucible and sample before ashing
W_2 = weight of crucible and sample after ashing.

Determination of Organic Matter

The organic matter content was calculated using the following formula

% Organic matter content = 100 - (% Ash + % Moisture)……………………Equation 3.0

Moistue content = $W_1 - W_2/W_1 * 100$

Ash content = $W_2/W_1 * 100$

Organic Matter content = initial weight - ash weight / initial weight * 100

Where W_1 is the weight of sample and W_2 is the weight dried sample.

Results and Discussion

Results

Biogas production

The pattern of daily biogas production for the 6 digesters is plotted against the retention time as shown in figure 1, 2 and 3, while some of the key points are listed in Tables 2 below.

Table 2: Daily biogas production and temperature readings

DIGESTR	*Commencement of gas production*		*Highest gas production*			*Last production day*		
	Volume (cm^3)	*Day (24Hours)*	*Volume (cm^3)*	*Day (24Hours)*	*Temp. (^OC)*	*Volume (cm^3)*	*Day (24Hours)*	Total volume of biogas yield from day 1-48 (cm^3)
D1	400	1	720	2	38	10	29	2575
D2	80	1	265	11	31	50	48	3455
D3	230	1	290	3	32	10	48	1005
D4	230	1	240	2	38	5	38	655
D5	80	1	80	1	38	35	48	1610
D6	125	1	165	26	28	85	48	1905

Proximate Analysis

The results obtained from parameters determined during the proximate analysis of the samples used in this work are shown in Table 3.

Table 3: Proximate analysis from the substrates

Sample	Ash content (%)	Moisture content (%)	Organic matter content (%)
Rice husks	85.0%	10.0%	5.0%
Cow dung	75.0%	15.0%	10.0%

Discussion

Daily Biogas production

Daily gas yield Rice husk to water ratios of 1:4 and 1:12

D_1 and D_4 both contained rice husk sample and was observed that all the digesters started biogas production in day one, with the highest gas yield in day 2 (720 cm^3 and 240 cm^3) respectively at an average temperature of 38°C. D_1 stop biogas production in day 29 with biogas volume of 10cm^3 while D_4 stopped biogas production in day 38 with biogas yield of 5 cm^3.

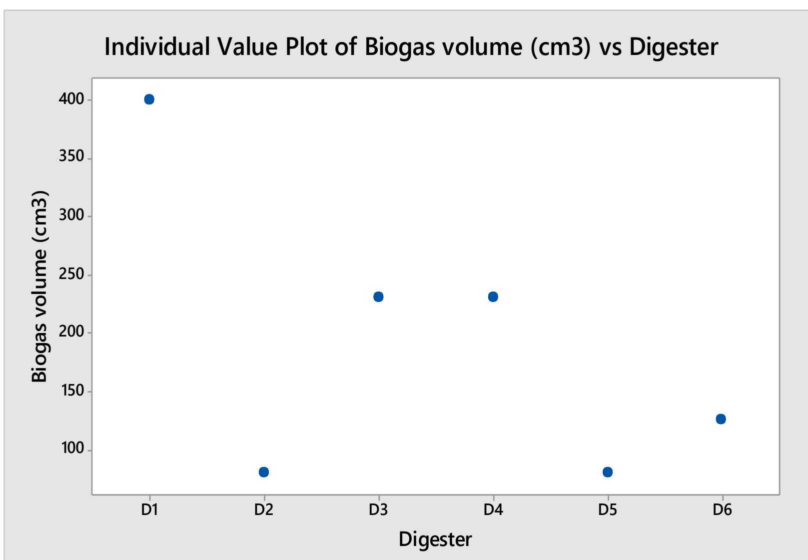

Figure 2: Results of commencement of biogas production from digesters

Daily gas yield Rice husk to Cow dung to water ratios of 1:1:4 and 1:1:12

It was observed that D_3 and D_6 which contain Rice husk plus cow dung samples and both digesters started biogas production in day one with volume of biogas production of 230 cm^3 and 125 cm^3 respectively. D_3 recorded the highest gas yield in day 3 and D_6 in day 26 with volume of 290 cm^3 and 165 cm^3 at an average temperature of 30°C. Both D_2 and D_5 didn't stop biogas production up to retention time for the experiment of 48days. D_2 and D_5 recorded the last biogas production of 10 cm^3 and 85 cm^3 respectively.

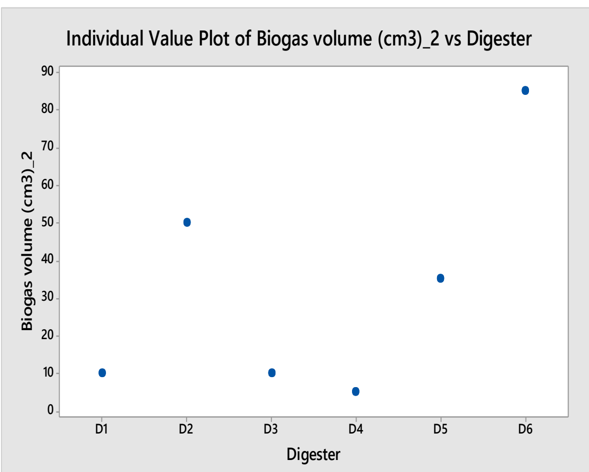

Figure 4: Results of last biogas production from digesters

Weekly Biogas Production

(a) Group A Digesters with Solid to Water Ratio of 1:4

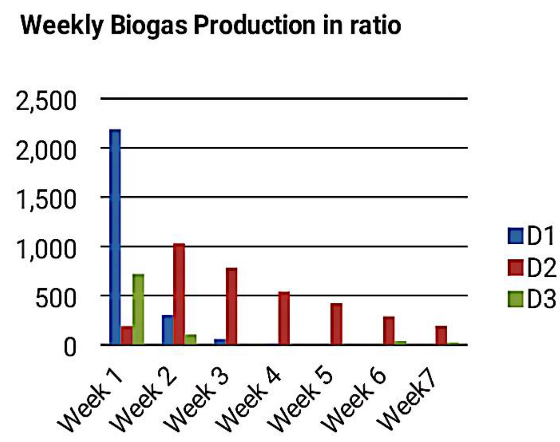

Figure 5: Results of weekly Biogas production in digesters from slurries 1:4 ratio

From the result obtained it can be seen that, in week one, Rice husk (D_1) produced its largest volume of biogas 2190.0 cm^3, followed by combination of Rice husk and Cow dung (D_3) which produced 720.0 cm^3, and lastly, Cow dung (D_2) that produced 190.0 cm^3. This result shows that the hydrolysis of Rice husk takes place faster than the hydrolysis of cow dung.

In the second week, cow dung (D_2) produced large amount (1030.0 cm^3) of biogas. The remaining digesters D_1, D_3, produced 305.0, 105.0, cm^3 of biogas. This shows that although the production for cow dung increased in the second week, the production for the other substrates decreased.

In the third week, cow dung (D_2) increased again to 785.0 cm^3, followed by D_1 with 60.0 cm^3, and D_3 produced only 5.0 cm^3. This result shows that only cow dung is producing biogas normally while the remaining substrates show poor production.

In the fourth week, the production for cow dung (D_2) decreases a bit low to the volume of 540.0 cm^3, then Rice husk (D_1) produced 15.0cm^3 a decrease over weeks 1, 2 and 3. The combination of Rice husk and Cow dung (D_3), produced 5.0 cm^3. Again, only cow dung is producing biogas normally.

In the fifth week, cow dung (D_2) still produced the largest biogas of (425.0 cm^3) amount of weekly biogas, although it has decreased compared with week 4. Then both D_1 and D_2 produced same amount of biogas of 5.0 cm^3 only. This also shows that only cow dung is producing biogas normally.

In the sixth week, cow dung (D_2) produced the largest amount (290.0 cm^3) of biogas, although it is lower than the production for weeks 2, 3, 4 and 5. Then D_3 produced the second largest (40.0 cm^3) biogas, while Rice husk (D_1) did not produce in the sixth week. Again, only cow dung produced large amount (290 cm^3) of biogas than others.

In the seventh week, both cow dung (D_2) and combination of Rice husk and cow dung (D_3) show a bit decrease in biogas production of 195.0 and 25.0 cm^3 respectively. Again, Rice husk (D_1) did not produce in the seventh week. Moreover; only cow dung produced large amount of biogas than others.

Therefore, it can be seen clearly that rice husk (D_1) and combination of rice husk and cow dung (D_3) gave their largest biogas production in the first week while Cow dung (D_2) did not produce a reasonable amount in the first week. Cow dung (D_2) gave largest biogas production in weeks 2, 3, 4, 5, 6 and 7 with the largest production happening in week 2. Even though digesters D_1, and D_3 which contain rice husk and combination of Rice husk and cow dung produced a reasonable amount of biogas in the first week; it can ironically be said that; both the digesters (D_1 and D_3) did not produce much biogas in the weeks monitored. This shows that rice husk affected the biogas production ability of cow dung.

(b) Group B Digesters with Solid to Water Ratio of 1:12

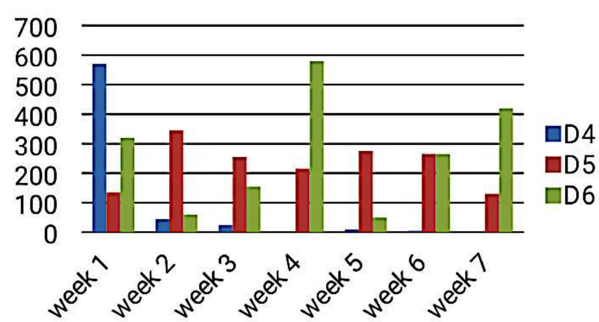

Figure 6: Results of weekly Biogas production in digesters from slurries 1:12 ratio.

From the result obtained (Fig .6), it can be seen that, all the digesters (D_4, D_5 and D_6) which contain rice husk, cow dung and combination of rice husk and cow dung started production in the first week with reasonable amount of biogas 570.0, 135.0 and 320.0 cm^3 respectively. This is quite different from the result obtained in group A. However, the pattern of production in the remaining weeks for D_4 and D_6 is also the same as for Group A, except that the volume of biogas produced in each week by D_4 is smaller while that of D_6 is higher than what was produced by the digesters in Group A. In fact, cow dung (D_5) still produced more biogas in each week with the largest biogas production of (345 cm^3) in week 2 again.

Also rice husk (D_4) have seen to show the same pattern of production with those in group A, with decrease in biogas production from week 3 to 7, although D_4 didn't produce biogas in week 4 and 7.

Effect of Slurry Dilution on Total Biogas Production

(a) Rice husk slurry

From the results obtained (Table 2) shows the total biogas production of rice husk slurry in the ratios, 1:4 and 1:12 It can be seen that the order of production is $D_1 > D_4$. Although there is no direct trend, this means that less dilute slurry is better for biogas production.

(b) Cow dung slurry

From the results obtained (Table 2) shows the total biogas production of cow dung slurry in the ratios, 1:4 and 1:12 It can be seen that the order of production is $D_2 > D_5$. This shows that low slurry and high slurry concentrations do not improve the biogas production of cow dung slurry. But, 1:4 slurry ratio is better slurry concentration for biogas production by cow dung.

(c) Rice husk plus Cow dung Slurry

From the results obtained (Table 2) shows biogas production from Digesters D_3 and D_6 which contains rice husk plus cow dung plus water in the ratio 1:1:4 and 1:1:12. Even though, there is no direct trend in the biogas production; it can be seen that biogas production from these digesters follow the order $D_6 > D_3$. This shows that most dilute slurry gave the largest production.

Proximate Analysis

Moisture Content

The results of the proximate analysis of the samples have been presented in table 3 above. It can be observed from the result that, after all the samples (rice husk and cow dung) were room dried and powered, the moisture content was calculated to be 10.0% and 15.0% for rice husk and cow dung respectively. This shows that the samples had about the same moisture content of about 12.5% which means that they are capable of developing some micro-organism if left uncovered.

Ash Content

The ash content was calculated to be 85.0% and 75.0% for Rice husk and cow dung respectively. Since ash content is a measure of the mineral element content of a sample, it means Rice husk should contain more mineral elements than the same weight of cow dung sample. This also means that Rice husk should contain more sodium, potassium, phosphorus, nitrogen, calcium and magnesium which will make a better bio-fertilizer than cow dung.

Organic matter Content

The organic matter content was calculated to be 5.0% for rice husk and 10.0% for cow dung. Therefore, since biogas is produced from the decomposition of organic matter of the substrates, it means cow dung will show the highest gas production than Rice husk, that is, the trend will cow dung > rice husk.

However, the results obtained in work show that for Set A digesters that have a solid to water ratio of 1:4, the total gas yield over the retention period of 48 days, the total gas production was 2575 cm^3 for rice husk and 3456 cm^3 for cow dung. This gives a trend of cow dung > rice husk, which is the same from the trend predicted by the organic matter content of the substrates.

Again, the total biogas production for Set B digesters that have a solid to water ration of 1:12 was 655.0 cm^3 for rice husk and 1620 cm^3 for cow dung which gives a trend of cow dung > rice husk, which is also the same from the trend predicted by the organic matter content of the substrates.

Conclusion

From the research conducted, it can be seen that biogas was produced from rice husk and compared with the biogas produced from cow dung; also the effect of slurry concentration on the production of biogas from these substrates has also been studied. From the results obtained, both samples (Rice husk and Cow dung) can make a better substrate for biogas production with the trend cow dung > rice husk, however; combination of rice husk with cow dung reduced the biogas production ability of rice husk in 1:1:4 and increased its ability in 1:1:12 ratios;

Also, from findings and the results of the effect of slurries, it may be concluded that, slurry concentration play a vital role in biogas production than substrate combination ratios with less slurry concentration showing a promising trend for optimum biogas yield as sustainable energy sources.

References

[1]. IEA (2006) “Energy for cooking in Developing countries” in : IEA WORLD ENERGY OUTLOOK 2006, OECD publishing 419-446.

[2]. Arthur., Zahran, S., and Bucini G. (2010) “On the adoption of electricity as a domestic

sources by Mozambian Households" Energy Policy 38, 7235-7249.

[3]. Nwabunwanne Nwokolo, Patrick M., KeChrist O., and Matthew E. (2020) A review paper, Waste to Energy: "A focus on the impact of substrate type in Biogas Production", Processes 2020, 8, 1224; doi:,3390/pr8101224

[4]. Smith, L. S., & Khatri-Chhetri, A. (2019). Biogas production from anaerobic digestion: A review. *Journal of Environmental Management*, 241, 293-301

[5]. Natonal Non-Food Crops Centre (2006): "Anaerobic Digestion Factsheet", https://www.bioenergy.org.nz/anaerobicdigestion.asp, Received on 08/10/2024.

[6]. Angelidaki, I., & Sanders, W. (2004). Assessment of the anaerobic biodegradability of macropollutants. Reviews in Environmental Science and Biotechnology, 3(2), 117-129.

[7]. Jena SP, Mohanty UK, Mahapatra S (2020). "Anaerobic digestion of semi-dried banana leaves in sewage water under the influence of certain additive. Mater today Proc. https://doi.org/10.1016/j.matpr.2020.02.830

[8]. www.en.wikipedia.org/wiki/Rice_hull, Rice hull, Assessed 19th March, 2025.

[9]. Xafir Ummul, (2021). "A detail note on cow manure" , *International Scholars' Journal*, Vol. 9, issue 1, pp 1-1.

[10]. www.en.m.wikipedia.org/Azare, Azare Profile, Accessed on 20th March, 2025

[11]. Y. Abdulrashid and A.A Zuru (2012). "Comparative studies on Biogas Production and Bio-fertilizer Potential of Cow dung, Neem seed and Neem seed Cake".Proceeding of PTDF-UMYUK international Conference on Renewable Energy, Katsina.

[12]. AOAC (1990) *Official Method of Analysis*, Washington DC, USA ; Association of Analytical Chemists, inch 4002 – 200 Wilson Boadlevard, Arlingo Verginia, 15th editioin pp 910 - 928