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Optimizing Biogas Generation from Blends of Sugarcane Bagasse

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ABSTRACT
Renewable energy has been the alternative source to global energy scarcity which involves renewable resources as more emphasis been put to prospective ways of converting agricultural wastes into energy to meet both the local and global demands.This work analyzed the use of sugarcane bagasse as substrate in biogas production as well as its codigestion with cow dung and chicken droppings. Seven digesters each of 2.5 litres capacity were charged in a ratio of 1:3 solids to liquid for a retention period of 30 days within a temperature range of 25-32 ^{o}C was used. Digester A contained 100 % bagasse, B contained 100 % cow dung, C 100 % chicken droppings, D contained 50 % bagasse and 50 % cow dung, E contained 50 % bagasse and 50 % chicken droppings, F contained 70 % bagasse and 30% cow dung and 70 % bagasse and 30 % chicken droppings for digester, G. Proximate and microbial analysis of the spent slurry were carried out. The result shows that sample C has the highest volatile solids and protein content of 56.68 % and 10.01 %. Biogas production was observed to be higher in digester C with cumulative gas yield of 3228.3 cm^3 then digester B with 2816.6 cm^3 and Digester A had the least gas yield of 681.4 cm^3. Lightening test was observed by passage over limewater which result in catching fire except on digester C. Methane and other traces of gases test using gas analyzer shows 61.3 % methane with the least having 46.7 % methane on digester B and C. Pseudomonas spp, Entrobacter aerogenes and Staphylococcus aureus were found to be dominant in almost all the digesters. Further research is required to investigate large volume production and to improve gas storage techniques.

Keywords:
Sugarcane bagasse,
Cow dung,
Chicken droppings,
Pseudomonas spp.,
Entrobacter aerogenes,
Staphylococcus aureus.

INTRODUCTION

Biogas production is a viable route in the search for sustainable and renewable energy sources, providing a cleaner substitute for traditional fossil fuels Cherwoo *et al.,* (2023). Sugarcane bagasse stands out as a promising option among the variety of biomass feedstocks available for biogas generation because of its widespread availability and capacity for effective conversion Zafeer *et al.,* 2023. In order to improve the sustainability and efficiency of bioenergy generation, this study investigates blends of sugarcane bagasse that optimize biogas production (Fioranelli and Bizzo 2023). Sugarcane bagasse, a byproduct of the sugar industry, consists of fibrous residues left behind after juice extraction from sugarcane. Its composition, rich in cellulose and hemicellulose, makes it an ideal substrate for anaerobic digestion, a microbial process that produces biogas as a valuable end product. The utilization of sugarcane bagasse in biogas production not only addresses the issue of agricultural waste management but also contributes to the development of acircular bioeconomy. Srivastava *et al. (*2023).

But optimizing the production of biogas from sugarcane bagasse is challenging task that calls for a careful balancing act between a number of variables, including process parameters, microbial activity, and substrate composition (Kumar *et al.,*2023). The production of biogas can be made more efficient overall by adjusting these variables through the blend of sugarcane bagasse with complementing feedstocks.In order to fully realize the potential of these blended substrates for sustainable biogas production, this study explores the synergistic effects of blending sugarcane bagasse with other biomasses (Santoyo-Castelazo *et al.,* 2023). The research explores not only the technical aspects of optimizing biogas production but also considers the economic and environmental implications of the proposed approach. By seeking a balance between resource utilization, energy

output, and environmental impact, this study contributes valuable insights to the ongoing efforts towards developing a more sustainable and resilient energy future (Arent *et al.,* 2022). As the world grapples with the challenges of climate change and the need for cleaner energy alternatives, the optimization of biogas production from blends of sugarcane bagasse represents a significant step towards a greener and more sustainable energy landscape. The aim of this study is to improve biogas generation from lignocellulosic sugarcane bagasse using anaerobic codigestion with cow dung and chicken droppings respectively.

MATERIALS AND METHODS

A batch type of anaerobic digestion was conducted, using 2.5 litre capacity batch digesters throughout the process. The daily volumes of biogas generated from each digester was collected and measured over water by downward delivery method as adapted by William *et al*., (2016). Proximate parameters such as moisture, ash, fat, crude protein and fibre content of the digested slurry were analyzed using AOAC, 1990 Nwokeocha *et al.,* (2023) as well as microbial loads were examined by method adapted by (Hassanein *et al.,* 2023). Quality test of biogas generated was carried out by lighting test and the estimation of methane content and other traces of unpurified gases were analyzed using Non-dispersed infrared analyzer.

Collection and Preparation of Samples

Sugarcane bagasse was procured from Katsina market (Yan kutungu), then washed with clean water for unwanted particles removal. Fresh cow dung was collected from Katsina abattoir as well as the chicken droppings from Darma farm Katsina; clean bags were used for the collection of the samples. The collected samples were subjected to sun drying for 7 hours of a week at the temperature range of 28-36^{o}C. The dried samples were pulverized using mortar and pestle. The pulverized samples were then sieved with 1mm size (William *et al*., 2016).

Bagasse Treatment

Hydrothermal treatment was performed according to William *et al*., (2016). The bagasse was treated at 170^{o} C for 2 hours in a ratio of 1:4 (w/v). In each digester, 400 g of grounded sample was weighed and mixed with 1.2 litres of distilled water making a ratio of solid to liquid to 1:3 (w/v) as reported by Ofamatah, (2011). The mixture was stirred thoroughly with a glass rod to achieve homogeneity.

Experimental Design

To conduct the experiment accurately, seven batch biodigesters marked A-G each of 2.5 litres capacity were used. Digester "A" contained 100% bagasse, "B" contained 100% cow dung, "C" 100% chicken droppings, "D" contained 50% bagasse and 50% cow dung, "E" contained 50% bagasse and 50% chicken droppings, "F" contained 70% bagasse and 30% cow dung and digester, "G" contained 70% bagasse and 30% chicken droppings. The digesters were tightly closed with cork to prevent air from entering and kept within 25-32 ^{o}C for a retention period of 30 days, one end of the tube was inserted inside each digester. 500 mL beaker was placed on the stand and clamp to measure the volume of displaced water. The volume of biogas produced as well as slurry temperatures from each digester were recorded at an interval of 24 hours. The digestion in all the processes was carried out without pH control, only that the pH of the slurry before and after digestion was recorded.

In carging of the digesters, the slurry occupied maximum of 75% while the remaining spaces were reserved for the gas that was produced.

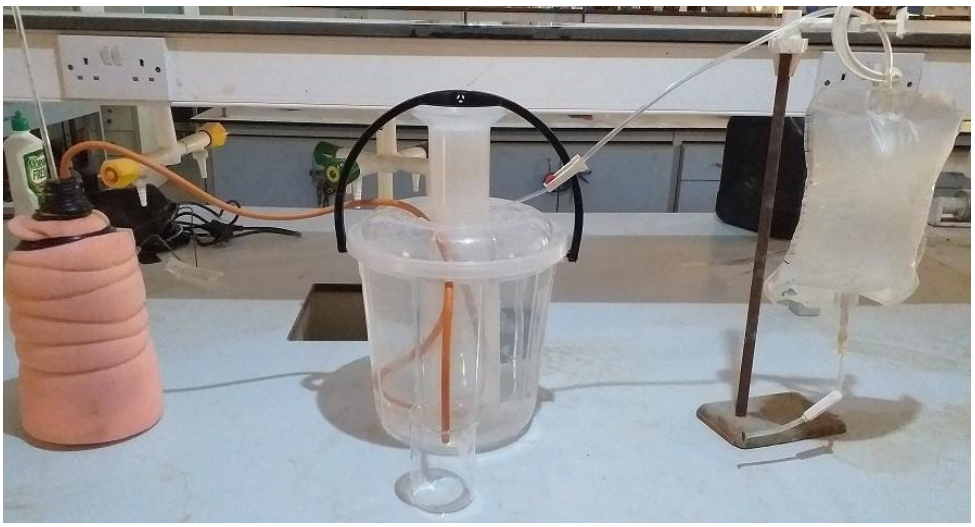

Figure 1: Biogas Production setup

RESULTS AND DISCUSSION

The digestion of the slurry was carried out within the mesophelic temperature range of 25-32^{o}C throughout the retention period of 30 days with the exception of day 17th, 22th and 26th which were observed to be less than 20^{0}C. This may probably the reason for zero production of biogas from digester, G, C and E. The fluctuation of temperature during the experiment has tremendously influenced the production of biogas. There was no biogas production from digester A, B, D & F for the first day, while to the second day from digester B as observed from Figure 2. This is undoubtedly traced to the fact that bagasse and cow dung are highly fibrous as investigated (Table. 2), and microorganisms takes longer time to degrade cellulosic and fibrous materials. This is closely in conformity with the existing literatures reported by Mutungwazi *et al.,* 2023 and share similarities to findings of Mohamed *et al.,* (2023) and Chorukova *et al.,* (2022) whose reported that biogas production was slow in the first week days of the process. The highest cumulative gas yield of 3228.2cm^3 was observed from digester C and the least of 681.4cm^3 from digester A, while for methane content; the result showed the highest of 61.3% with the least having 46.7% on digester B and C respectively as presented in Table 1. The rate of biogas yield over the digestion period of the experiment was irregular and have a peak gas production yield on 24th , 16^{th,} 14th , 14th 12th , 19th , 13th , and 15th days yielding to 43.4 cm^3, 182.6 cm^3, 188.0 cm^3, 98.6 cm^3, 99.2 cm^3, 68.8 cm^3 and 89.8 cm^3 from digester A,B,C,D,E,F and G respectively as illustrated in Figure 2, this may be due to the phases of microbial growth. The digester A affected the total biogas yield this may be traced to the fact that other digesters contained a multiple carbon source, that is contain either of cow dung or chicken droppings as inoculums unlike digester A. The values of physiochemical parameters obtained upon the proximate analysis showed that sample C was found to have some higher energy yielding nutrients (protein, fat and volatile solids) with lower fibre and carbohydrate content than corresponding's of A, B, D, E, F and G (Table 2). The pH of the slurry monitored before and after digestion was in favourable for microbial growth with the exceptions of that obtained from digester A and F (4.8 to 5.9 and 5.6 to 6.1) respectively. This was also in evident in the low amount of biogas generated from digesters A and F, hence biogas production was increased as the slurry pH maintain between 6.6 to 7.6 with highest range of 7.0 to 7.2, and bacteria responsible for biogas production becomes inactive as slurry pH lower than 6.2 (Ofamatah, 2011).

Quality Test and Estimation of Methane Content

The quality test of biogas produced was conducted over limewater, after which it was connected to Bunsen burner for lightening. The results showed flammable gas was obtained with the exception of that generated from digester C. This may likely be associated with the presence of *Salmonella* spp and high protein content from chicken droppings which may likely increase production of high quantity of hydrogensulphide (H_2S) gas which do not support combustion. The relative percentages of methane and other gases in biogas depend on the type of substrates and the management of the digestion process. The methane content obtained from both digesters was within the quality range for biogas suggested by (Wadchasit *et al.,* 2023) with the exception of that obtained from digester C as presented in Table 1and agreed with other reports of William *et al*., (2016). The highest methane value was observed from digester B and the least was from digester C as clearly illustrated in Figure 3.

Microbial Assessment

The spent slurry in the digesters was subjected to microbial analysis using the reported method. The microbial loads expressed as colony-forming units (cfu) of the samples, the occurrence of bacterial count ranged from 2.1x10^{7}cfu/g in sample C to 28.8x10^5 in sample F and fungal count ranged of 0.6x10^7 cfu/g in sample C to 28.6x10^5 cfu/g in sample E. Sample C had the highest bacterial count while the highest fungal count was observed from sample B as shown in Figure 4. The microbial isolates in the digesters spent slurry were *Salmanella* spp, *Escherichia coli, Entrobacter aerogenes, Staphyloccocus* spp, *Pseudomonas* spp, *Aspergillus flavus, Rhizopus, Saccaromyces* spp, *Penicillium* spp and *Fusarium oxysporum*; this was closely in conformity from the findings of Joshi, (2020) and Rabah *et al*., (2010). It was also reported that *Pseudomonas* spp was responsible for biogas production in cow dung slurry (Hassan *et al.,* 2022). The microbial isolates were responsible for the degradation of macromolecules to intermediates such as carbonic acids which were ultimately further converted to biogas. The identified microbes from the wastes may cause diseases to human beings including skin infections.

Table 1: Summary of Gas Yield/Methane Content (%)

Digesters	Cumulative Volume (cm^3)	Average Volume (cm^3)	Methane Content (%)	Peak Production (cm^3)	Least Production (cm^3)	PPD	LPD
A	681.4	22.7	57.2	43.4	7.8	24	14
B	2816.6	93.9	61.3	182.6	35.4	16	3
C	3228.3	107.6	46.7	188	22.8	14	1
D	1732.5	57.8	58.4	98.6	1 8.6	12	27
E	1989.2	66.3	51.2	99.2	12.4	19	1
F	1172.6	39.1	50.6	68.8	16.4	13	30
G	1385.8	46.2	54.1	89.8	8.0	15	30

PPD: Peak Production Day LPD: Least Production Day

Table 2: Physiochemical Properties of the Digested Slurry

Parameters	A	B	C	D	E	F	G
Moisture %	25.60	28.22	19.50	26.46	22.60	27..56	21.45
Ash %	3.40	3.38	12.43	3.52	6.24	3.45	5.34
Protein %	1.50	2.25	10.01	2.81	7.82	1.94	5.10
Fat %	2.26	1.82	9.55	2.14	5.05	2.38	4.54
Crude fibre %	34.62	44.30	23.87	38.94	26.84	36.36	31.74
Carbohydrate %	32.57	20.03	24.64	26.13	31.45	27.31	31.83
Total solids %	74.30	71.78	80.50	68.54	77.40	72.44	78.54
Volatile solids %	52.42	31.4	56.68	35.95	49.48	43.79	39.58
Fixed carbon %	18.53	37	11.39	34.07	21.68	25.20	33.63
Nitrogen %	0.24	0.68	2.24	0.45	1.25	0.31	0.82
pH B/4 Digestion	4.8	6.7	6.6	7.1	6.1	5.6	6.5
pH After Digestion	5.9	7.4	7.2	6.7	6.6	6.4	7.4

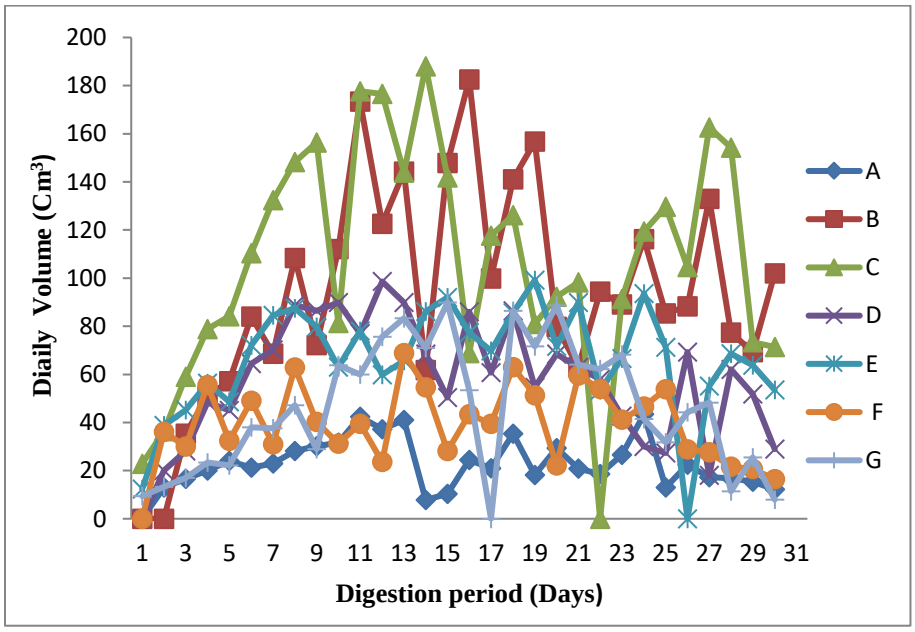

Figure 2: Daily Volume of Gas Produced

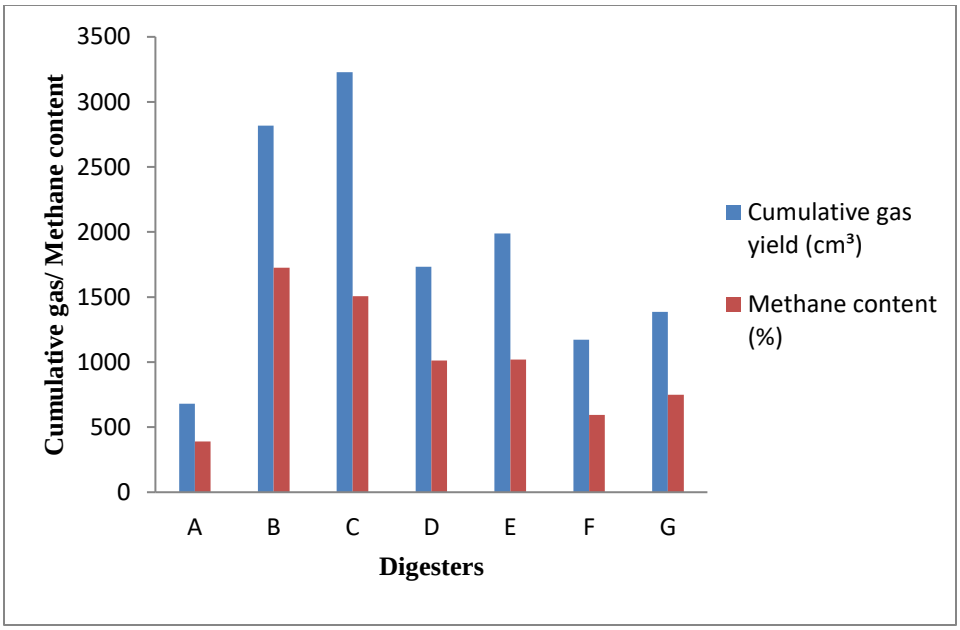

Figure 3: Cumulative gas Vs Methane

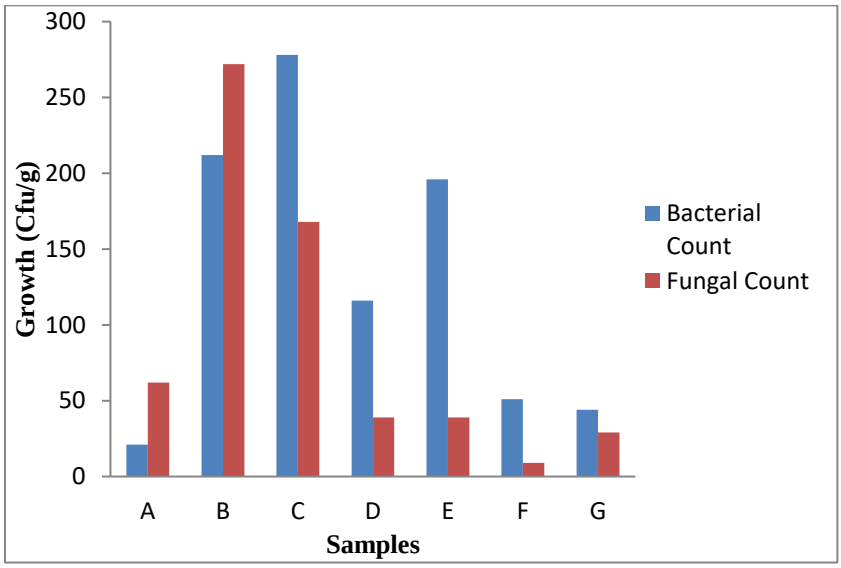

Figure 4: Bacterial Vs Fungal Count upon the Digested Slurry

CONCLUSION

It has been shown that sugarcane bagasse can be utilized as a biogas generation substrate. Additionally, it has been demonstrated that codigestion with chicken droppings or cow dung may increase output. While the composition of the substrate affects the quality of the gas produced, codigesting cow dung with other sources of carbohydrates might enhance the gas's quality. Anaerobic digestion is another effective method for turning biomaterials into profitable endeavors. The low production of biogas from sugarcane bagasse is caused by its high cellulose concentration. It was discovered that the chicken poop included viruses that may infect humans and cause illnesses including skin infections. It has been shown that sugarcane bagasse can be utilized as a biogas generation substrate.

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