Ethiopian Journal of Science and Sustainable Development

e-ISSN 2663-3205 Volume 10 (1), 2023

Journal Home Page: www.ejssd.astu.edu.et

EJSSD
ETHIOPIAN JOURNAL OF SCIENCE AND SUSTAINABLE DEVELOPMENT
An Official International Journal of Adama Science and Technology University

Research Paper

Production of Biogas from Calabash Waste Mixed in Selected Ratios with Sheep and Donkey Dungs

Tewabech Temesgen Mekonnen* , Moges Admasie Mengstie, Fasika Kebede Shewareged

Department of industrial chemistry, College of Science, Bahir Dar University, Bahir Dar, Ethiopia

Article Info

Article History:
Received 13 April 2022
Received in revised form 20 August 2022
Accepted 30 September 2022

Keywords:
Biogas,
Calabash Waste,
Retention Time,
Anaerobic Digestion

Abstract

Anaerobic digestion process is one of the non-thermal technologies of energy recovery to meet the ever-growing energy demand of rural areas in developing countries, particularly Ethiopia, in a green way. The aim of the present study was to investigate the effectiveness and performance characteristics of anaerobic digestion of calabash waste mixed in selected ratios with donkey and sheep dung for biogas production. Production of biogas from calabash waste, mixed with donkey and sheep dung in ratios 1:1, 2:1, 3:1, and 4:1 by mass, was investigated in a 45 L plastic container using a retention period of 20 days and within the mesophilic temperature range. The average biogas yield was significantly ($P \leq 0.05$) influenced by the different mixing ratios of calabash waste with dung. The composition of gas generated from each ratio ranged (from 67.41-63.81)% CH_4, (33.00-26.01)%, CO_2, (1.06-0.40)% CO, (3.00-0.07)% H_2O, (0.06-0.02)% NH_4,(0.90-0.05)% N, (0.72-0.02)% H, (0.98-0.09) % O_2, and (0.006-0.001) % H_2S. The average biogas yield was 13.5, 11.6, 10.7, and 7.8L respectively for 1:1, 2:1, 3:1, and 4:1 mixing ratios when calabash waste was mixed with sheep dung. On mixing calabash waste with donkey dung, the average biogas yield increased to 16.2, 15.5, 12.6, and 9.8L respectively for 1:1, 2:1, 3:1, and 4:1 mixing ratios. The results show that mixing both dungs with calabash waste in a ratio of 1:1 by mass-produced the highest biogas volumes, and higher in donkey dung. The reason behind this is that higher mixing ratios meant a higher quantity of waste in the mixture which also implied increased lignin content, and this made digestion activities more difficult for the microbes. Reduction in digestion activities of the methanogen bacteria resulted in lower biogas yield. The result of the present study has shown that anaerobic digestion from calabash waste, mixed with donkey and sheep dung in ratios 1:1, 2:1, 3:1, and 4:1 by mass can form a renewable energy that is comfortable and environmentally friendly. This energy production process is found to be an easy way of replacing fossil fuels.

1. Introduction

Energy is one of the prerequisites for the growth of agriculture and industry (Rai and Da Silva, 2017). The energy requirements are met mainly through commercial energy sources such as oil and natural gas (fossil fuel). Fossil fuels are exhausting and their toll on humanity is high in terms of environmental degradation, the spread of disease, and climate change/global warming via Greenhouse gas (GHG) emissions (Shane and Gheewala, 2017). Currently, the prices of these commercial energy sources have increased gradually and there is a continuous depletion of these scarce resources (Arrhenius et al., 2019). The global quest for renewable and sustainable energy generation has been

*Corresponding author, e-mail: Tewabech.Temesgen@bdu.edu.et

https://doi.org/10.20372/ejssdastu:v10.i1.2023.458

incessantly increasing over the years as the sequence of the increasing world population (Arrhenius et al., 2019)

The world's demand for energy grows rapidly, and therefore, it is time to look for alternative and renewable energy resources to replace the rapidly depleting supply of fossil fuels. Many countries have realized that biogas is a source of energy that is highly needed for sustainability transition (Bahr et al., 2014; Nevzorova and Kutcherov, 2019). However, the total production volume of biogas in developing countries is still relatively low (Gemechu, 2020). Such slow development raises a fundamental question—what are the current barriers hindering the wider uptake of biogas as a source of energy. To this end, there is a need for the integration of cleaner production technologies in solving the world's numerous environmental challenges most especially the issues in energy generation and utilization by using locally available organic waste and dung (Kumar et al., 2014; Faizalet al., 2018).

Biogas is one of the good and promising sources of alternate energy(Sawyerr et al., 2019). This energy can be harnessed successfully to meet the existing as well as future needs of rural areas. Biogas is a renewable energy source produced from organic material (agricultural waste, dung, municipal waste, vegetable waste, sewage, green waste, or food waste), which is broken down with the help of bacteria in an anaerobic (oxygen-free) environment (Ighravwe et al., 2018). It has been used as a viable alternative fuel for a variety of domestic purposes in different countries, notably China and India (Muzenda, 2014). Depending on the nature of the organic compound, the complexity of the process will increase and the step of anaerobic digestion will also change to some extent (Mulat and Horn, 2018). In this process, several steps are involved and several microorganisms are responsible for these steps of anaerobic digestion (Miah et al., 2016). The flow chart (steps) of aerobic digestion is depicted in Figure 1 (Ngan et al., 2020).

2. Materials and Methods

2.1. Materials

In this experiment, Fresh Calabash wastes, donkey and sheep dung, plastic containers, and water were used as feedstocks. In this work, a floating dome-type collector, that is, a movable gas holder biogas digester was used. A gas collector, mixer and grinder (BX-1002) were also employed. Necessary chemicals such as ash and others were added to regulate the pH change.

2.2. Methods

2.2.1. Collection & Preparation of Raw Materials

Fresh Calabash wastes were collected from around Gordema farms, 3km from Bahir Dar City, Ethiopia. Sticks, stones, leaves, and other foreign matter were then hand-picked from the mass of collected waste, after which the waste was chopped, pounded and stirred to break into smaller particles to ensure the consistency of the mix. Fresh donkey and sheep dung were collected from the livestock farms at Zezelema Farms, 5km from Bahir Dar city. Stones and sticks were removed from the dung, which was finally thoroughly stirred.

i) Chemical & physicochemical analysis of blends

The blends of calabash waste and donkey and sheep dung of each ratio were dried and ground into smaller particles to increase the surface area of the blends. These ground blends were brought to the Soil Research Centre at Bahr Dar for further analysis. The analysis of the blends was performed at the Department of National Soil Research Centre in Bahir Dar following standard procedures (Ryan et al., 2001; Tuzen et al., 2008). Kjeldahl digestion and distillation apparatuses were used to determine the nitrogen (N) content of the blends (Hicks et al. 2022). The carbon content of the blends was measured with the help of the method found by Wang and Geng (2015). A flame photometer was used to determine the content of sodium (Na) and potassium (K) in the blends (Banerjee and Prasad, 2020). The contents of Copper (Cu) and zinc (Zn) in the blend were analysed using atomic absorption spectrophotometer (Siraj and Kitte, 2013). The content of Phosphorus (P) in the blend was analysed by spectrophotometer, the method described by Adelowo and Oladeji (2016). The content of ammonium (NH4) in the blends was determined by the method described by Gates et al., (2005). This instrumental analysis was performed in triplicates, and the average result was taken. Moisture content, ash content, lignin content, total solid and volatile solid of the blends of calabash waste with donkey and sheep dungs of each ratio were determined by the methods described by Sluiter et al., (2008); Pieces et al., (2014); Fagerstedt et al., (2015).

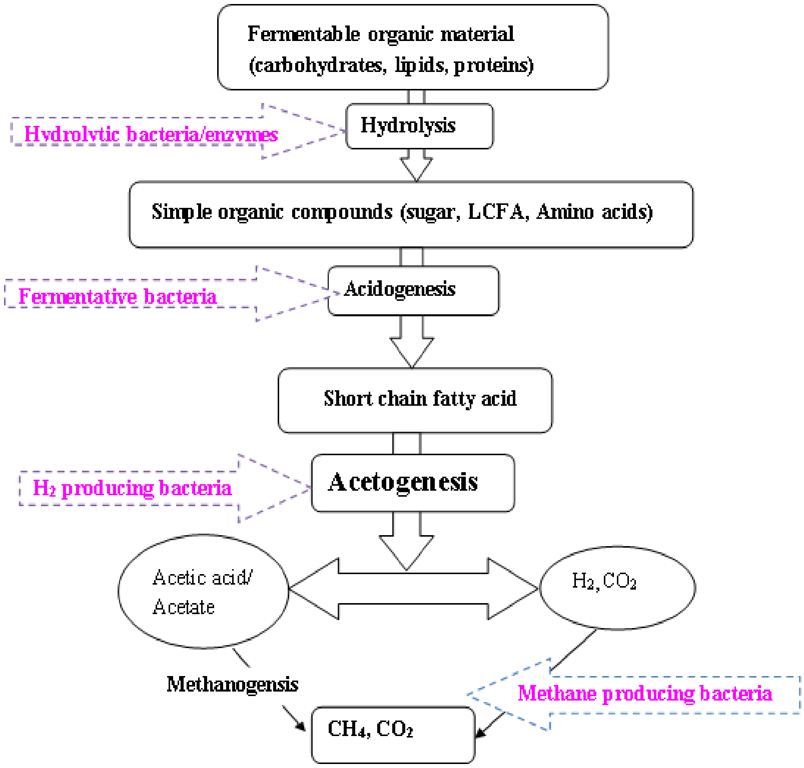

Figure 1. Flow chart / steps of an aerobic digestion

2.2.2. Biogas production

The effect of calabash waste mixed with the donkey and sheep dung in the ratios 1:1, 2:1, 3:1, and 4:1 for biogas production was investigated in a 45L plastic container, using a 20-day retention period. Two kilograms (2kg) of calabash waste and 2kg of dung were measured and mixed thoroughly in a 45L plastic container. The mixture was further mixed with 20L of water and 0.4kg of firewood ash. The slurry was then stirred with a wooden stick to mix the contents thoroughly. The pH of the slurry was then checked with litmus paper and found to be around 8. A 25 L gas collector, with the open end directed into the bio-digester containing the slurry and having a gas outlet at the top was gently pushed into the digester to remove any atmospheric gas found in the bio-digester. A hissing sound was heard showing that air is being pumped out which eventually faded. At this point, the gas outlet was closed from where the digestion process for biogas generation started. The pH of the slurry was recorded daily by using litmus paper. Biogas production was measured daily on a volume basis by water displacement. The ambient temperatures on site were continually measured using a maximum and minimum thermometer and recorded throughout the retention period. Biogas samples were obtained on Day 6 and Day 20 of the retention period and the generated biogas was collected using a gas collector and analysed for methane content using a gas detector, Gas chromatograph- Mass spectrometer (GC-MS) (Model: GC-7820A, Agilent Technologies; Detector-5977EMSD, USA) Column: DB-1701. Instrumental analysis was performed three times and average results were taken.

The same procedure was repeated for ratios 2:1 (2kg of waste, 1 kg of dung, and 0.2kg of ash with 15L of water added), 3:1 (3kg of waste, 1kg of dung, and 0.1kg of ash with 30L of water added) and 4:1 (3.5kg of waste, 1.5kg of dungs, and 0.2kg of ash with 25L water added). Each digestion process was run in triplicates to see the reproducibility of the results.

2.2.3. Statistical analysis

Statistical data were analysed with SPSS version 23. Multi variant (one-way ANOVA with blocking) statistical package was used in analysing the average biogas measurement for their significance within the different mixing ratios and between calabash waste and dung.

3. Results and Discussion

3.1. Chemical and physicochemical analysis

The results of the chemical analysis of blends in each ratio such as %K, %P, %NH4, %Na, %Zn, %Cu, %Lignin, %moisture content, and % ash are shown in Table 1. The results are consistent with other results reported elsewhere (Adelekan and Bamgboye, 2009; Yaru et al., 2014 andTsapekos et al., 2017). The values of moisture content in the blends ranged from (86.861-88.451) %; this optimum moisture content is favourable for the enhancement of biogas yield (Sorathia et al., 2012). The values of lignin content in the blends ranged from (0.941-1.923) %; these lower values are favourable for enhancing the methane yield and hydrolysis rate significantly (Piątek et al., 2021; Zhang et al., 2021). The values of ash content in the blends ranged from (2.341-1.792) %; these values are desirable for biogas production(Jijai et al., 2017). The contents of macronutrients (%K, %P, %Na, and % NH_4) and micronutrients (% Zn, % Cu) in the blends are desirable and good for further application as Bio fertilizer after biogas production(Siswanti et al., 2019; Audu et al., 2020).

Table 1: Chemical analysis of blends in each ratio

Blends	Ratio	%K	%P	%NH_4	%Na	%Zn	%Cu	Lignin, (%)	Moisture content,%	%Ash
Calabash Waste (CW) with Donkey Dung (DD)	1:1	0.231± 0.040	0.085± 0.041	0.951± 0.081	0.023± 0.014	0.003± 0.002	0.005± 0.004	0.941± 0.501	88.340± 0.980	2.051± 0.090
	2:1	0.512± 0.051	0.065± 0.032	0.842± 0.150	0.045± 0.023	0.005± 0.003	0.004± 0.002	1.732± 0.603	88.30± 0.871	1.930 ± 0.160
	3:1	0.410± 0.030	0.042± 0.014	0.634± 0.109	0.051± 0.016	0.004± 0.002	0.002± 0.001	1.568± 0.510	87.41± 0.851	1.981± 0.510
	4:1	0.321± 0.021	0.036± 0.015	0.581± 0.091	0.073± 0.034	0.002± 0.001	0.003± 0.001	1.653± 0.440	86.92± 0.691	1.891± 0.409
Calabash Waste (CW) with Sheep Dung (SD)	1:1	0.234± 0.060	0.071± 0.031	0.741± 0.150	0.054± 0.032	0.002± 0.001	0.006± 0.002	1.521± 0.075	87.340± 0.670	1.851± 0.093
	2:1	0.124± 0.045	0.231± 0.061	0.651± 0.095	0.065± 0.014	0.003± 0.001	0.005± 0.003	1.731± 0.150	86.861± 0.643	1.792± 0.130
	3:1	0.091± 0.012	0.141± 0.051	0.561± 0.034	0.076± 0.032	0.001± 0.001	0.002± 0.001	1.851± 0.460	88.451± 0.741	2.341± 0.230
	4:1	0.312± 0.042	0.341± 0.043	0.751± 0.084	0.077± 0.014	0.002± 0.001	0.001± 0.001	1.923± 0.270	87.921± 0.571	1.941± 0.461

Table 2: Physicochemical analysis of blends in each ratio

Blends	Ratio	Total solid (%)	Volatile solid (%)	Carbon content (%)	Nitrogen content (%)	Carbon to Nitrogen ratio (C:N)
Calabash Waste with Donkey Dung	1:1	4.84±1.20	22.60±0.90	27.12±1.01	1.24 ±0.71	27:1±1.40
	2:1	6.84±1.20	40.32±0.81	24.31±0.81	1.42±0.91	24:1±0.89
	3:1	9.30±0.51	60.12±1.02	24.48±0.52	1.04±0.61	24:1±0.85
	4:1	10.23±0.70	75.31±0.41	26.53±0.72	1.61±1.02	26:1±0.71
Calabash Waste with Sheep Dung	1:1	3.76 ±0.53	25.21±0.56	26.65±0.42	1.34±0.61	26:1±0.69
	2:1	5.94±0.92	39.34±0.46	25.41±0.64	1.24±0.95	25:1±0.67
	3:1	8.45±0.74	82.32±0.58	24.54±0.59	1.41±0.68	24:1±0.87
	4:1	11.03±0.85	59.57±0.63	26.54±0.72	1.23±0.69	26:1±1.04

The result of the physicochemical analysis of the blends in each ratio is shown in Table 2. This result agrees with Guarino et al., (2016) and Choi et al., (2020). The carbon-nitrogen (C/N) ratio of the blends was obtained from the physicochemical analysis. One to One (1:1) ratio of waste mixed with donkey dung had the highest C/N ratio of 27.12, followed by a 1:1 ratio of waste with sheep dung (26.65), 4:1 ratio of waste with sheep dung (26.57), 2:1 ratio of waste with sheep dung (25.41), 3:1 ratio of waste with sheep dung (24.54), 3:1 ratio of waste with donkey dung (24.48), and 2:1 ratio of waste with donkey dung (24.31). Generally, all the selected ratios had the optimum C/N ratio, and this result is found to be good for biogas production (Sreekrishnan et al., 2004; Guarino et al., 2016). Having an optimum C/N ratio has been suggested for the anaerobic digestion process because a very high or low C/N ratio may inactivate microbes in the anaerobic digestion processes, which reduces the activity of methane-producing bacteria and activate other side products forming bacteria (Baum et al., 2002; Jos et al., 2018). The result of the blends in all digesters was high in %VS but low in % TS. This high volatile matter content was anticipated because of the organic nature of the material used. The contents of volatile matter in biomass materials are usually high due to the organic nature of the biomass (Sajeena et al., 2013; Syaichurrozi and Sumardiono, 2014; Orhorhoro et al., 2017). Generally, the results of total solid, volatile solid and carbon to nitrogen ratio of calabash waste with donkey dung and calabash waste with sheep dung in each ratio were different, and these different may be due to the content of dung & the conditions of anaerobic digestion process (Mukumba et al.,2016; Nagy et al.,2019).

3.2. Composition of biogas from mixture of calabash waste with donkey and sheep dung

The samples of the biogas generated from all the digesters were collected and analysed using a gas detector (Nwagbo et al., 1991; Liu et al., 2018). Table 3 and Table 4 show the result of the composition of biogas from the mixture of calabash waste with donkey dung and calabash waste with sheep dung respectively. The results of this study are in a comparable range with the findings reported in some studies elsewhere (Carcelon and Clark, 2002; Koch et al., 2015). The 1:1 ratio of waste mixture with donkey dung had the highest CH_4 content (67.41±0.98 %) and its CO_2 value is (27.23±0.81 %), followed by the 3:1 ratio of waste with donkey dung (66.91±0.68 %) with CO_2 value of (26.01±0.56 %), 1:1 ratio of waste with sheep dung (66.90 ±1.23 %) with CO_2value of (29.23±0.76 %), 2:1 ratio of waste with donkey dung (66.50±1.05) with CO_2 value of (28.09 ±0.67 %), 4:1 ratio of waste with donkey dung (65.61±0.49 %) with CO_2 value of (31.06±0.39 %), 2:1 ratio of waste with sheep dung (65.510±1.09 %) with CO_2 value of (32.00±0.86 %), 3:1 ratio of waste with sheep dung (65.12±0.98 %) with CO_2 value of (31.03±0.59 %), and CH_4 content of 4:1 ratio of waste with sheep dung (63.81±0.69 %) with CO_2 value of (33.00±0.79 %). Trace levels of CO, H_2O, NH_4, N, H, O_2, and H_2S are also presented in this result. The reason for the low value of methane content is probably because significant quantities of carbon dioxide and other non-combustible gasses were produced in the anaerobic digestion of calabash waste with sheep dung (Carcelon and Clark, 2002; Piątek et al., 2021).

Table 3. Composition of biogas from mixture of calabash waste with donkey dung

Components	**Concentration (by volume) in %**			
	1:1	2:1	3:1	4:1
Methane(CH_4)	67.41±0.98	66.50±1.05	66.91±0.68	65.61±0.49
Carbon dioxide (CO_2)	27.23±0.81	28.09 ±0.67	26.01±0.56	31.06±0.39
Carbon monoxide (CO)	0.70 ±0.65	0.90±0.18	0.40±0.91	0.60±0.46
Water (H_2O)	2.90 ±0.74	3.00 ±0.73	1.51±0.56	2.06±0.29
Ammonia (NH_4)	0.04±0.64	0.03±0.23	0.05±0.47	0.02±0.01
Nitrogen (N)	0.05±0.73	0.08±0.51	0.90±0.08	0.31±0.38
Hydrogen (H)	0.09 ±0.19	0.02±0.01	0.08 ±0.06	0.05±0.01
Oxygen (O_2)	0.81±0.04	0.91±0.03	0.61±0.05	0.09 ±0.02
Hydrogen sulphide (H_2S)	0.003±0.01	0.005±0.01	0.004±0.02	0.002±0.01

Table 4: Composition of biogas from mixture of calabash waste with sheep dung

Component	Concentration(by volume) in%			
	1:1	2:1	3:1	4:1
Methane (CH_4)	66.90 ±1.23	65.510±1.09	65.12±0.98	63.81±0.69
Carbon dioxide (CO_2)	29.23±0.76	32.00±0.86	31.03±0.59	33.00±0.79
Carbon monoxide (CO)	0.81±0.52	0.60 ±0.05	1.06 ±0.60	0.90±0.32
Water (H_2O)	0.90 ±0.04	0.08±0.05	0.90 ±0.04	0.07 ±0.02
Ammonia (NH_4)	0.05±0.03	0.04±0.02	0.06±0.30	0.03 ±0.01
Nitrogen (N)	0.70±0.04	0.65±0.05	0.51±0.31	0.49±0.23
Hydrogen (H)	0.09±0.12	0.08 ±0.09	0.72±0.28	0.05±0.14
Oxygen (O_2)	0.91±0.50	0.98±0.07	0.40±0.01	0.75±0.06
Hydrogen-sulphid(H_2S)	0.003±0.002	0.006±0.001	0.002±0.001	0.004±0.001

3.3. Average biogas measurement from the mixture of calabash waste and dung

The results of the average biogas measurements of each ratio are found to be comparable with the values in some studies reported elsewhere (Adelekan and Bamgboye, 2009; Mukumba et al., 2016; Alkhamis et al., 2021). The average biogas measurement decreases by a 1:1 to 4:1 ratio in all ratios, as illustrated in Table 5. Statistical analysis also shows that the average biogas yield was significantly ($P \leq 0.05$) influenced by the different mixing ratios of calabash waste and dung, as shown in Table 6, Figure 2 and Figure 3. This means that the 1:1 ratio has a greater biogas yield than the 2:1 ratio, a 2:1 ratio greater biogas yield than the 3:1 ratio, and a 3:1 ratio greater biogas yield than the 4:1 ratio. In 1:1, the ratio gets higher biogas yield and the 4:1 ratio gets the least biogas; thus, when the amount of waste increases and the dung decreases, the yield of biogas diminishes. The reason behind this is that higher mixing ratios meant a higher quantity of waste in the mixture, which also implied increased lignin content and this made digestion activities more difficult for the microbes(Mulat and Horn, 2018). Reduction in digestion activities of the methanogen bacteria resulted in lower biogas yield. Furthermore, with time, the waste rapidly ferments and becomes more acidic. Acidic environment is not well tolerated by anaerobic bacteria; therefore, their rapid multiplication will be severely curtailed at the higher mixing ratios which contained more waste in the mixture (Abubakar et al., 2004;Chellapandi, 2004;Adelekan and Bamgboye, 2009). In general, the average biogas yield of waste mixed with donkey dung is higher than the average waste mixed with sheep dung in every successive ratio. This low value is due to the fact that the body of sheep dung is solid as compared with donkey dung and less amount of fermentative bacteria is found in sheep dung. This makes it not easily fermented in the microbes (Adelekan and Bamgboye, 2009; Alkhamis et al., 2021).

3.4. Effect of variation of pH on/ during the digestion period

The microorganisms are sensitive to pH because each group survives at different ranges. From Figure 4 and Figure 5, we can see that the pH of waste with donkey dung and sheep dung in each ratio was 8 (Day one), but the pH reduces as the process goes on and as the bacteria produces fatty acids. Here, methanogens bacteria that utilize fatty acids is a slow reaction, compared to other bacteria, so it is the rate-limiting step in the reaction (Al Mamun and Torii, 2014; Jos et al., 2018). Furthermore, waste with sheep dung in each ratio pH decreases highly and the reaction is fast, which means that the hydrolysis and acidogenesis reaction is fast as the organism utilizes the waste more speedily than waste with donkey dung (Figure 4). Thus, the yield of biogas is decreased compared to the mixture of waste with donkey dung (Mukumba et al., 2016; Alkhamis et al., 2021). Thus, the result of the pH measurements of each ratio is compatible with Jos et al. (2018) and Victor et al., (2018).

The anaerobic fermentation study was investigated within the daily ambient temperature range of 25.3°C to 37.9°C for all the digesters. The lowest temperature reading of 25.3°C was obtained on the 9th day while the highest temperature of 37.9°C was recorded on the 16th day of digestion process and the other records fluctuated within this range. Therefore, at constant, mesophilic temperature ranges the methane-producing bacteria convenient for the fermentation process and would give better gas yield (Getahun et al., 2014; Liu et al., 2018).

Table 5: Summary of average biogas measurement from mixtures of calabash waste and dung

Component	**Average biogas volume of each ratio(L)**			
	1:1	2:1	3:1	4:1
Waste with donkey dung	16.2±1.08	15.5 ± 0.86	12.6±0.76	9.8±0.64
Waste with sheep dung	13.5± 0.94	11.6 ±0.65	10.7±0.62	7.8± 0.57

Table 6: Effect of different mixing ratios of waste and dung on average biogas yield Test of between-subject effect

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	biogas yield for wwdd	76.613[a]	3	25.538	1532.267	.000
	biogas yield for wwsd	52.283[b]	3	17.428	275.171	.000
Intercept	biogas yield for wwdd	2197.813	1	2197.813	131868.800	.000
	biogas yield for wwsd	1423.541	1	1423.541	22476.961	.000
Ratio for wwdd and wwsd	biogas yield for wwdd	76.613	3	25.538	1532.267	.000
	biogas yield for wwsd	52.282	3	17.427	275.171	.000
Error	biogas yield for wwdd	.133	8	.017		
	biogas yield for wwsd	.507	8	.063		
Total	biogas yield for wwdd	2274.560	12			
	biogas yield for wwsd	1476.330	12			
Corrected Total	biogas yield for wwdd	76.747	11			
	biogas yield for wwsd	52.789	11			

R Squared = .998 (Adjusted R Squared = .998); b. R Squared = .990 (Adjusted R Squared = .987)
Where wwdd = waste with donkey dung and wwsd =waste with sheep dung

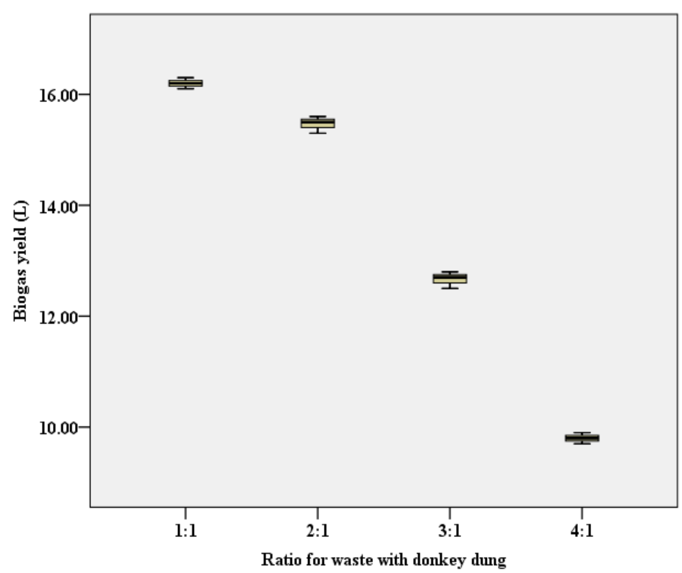

Figure 2. Effect of different mixing ratios of waste and donkey dung on average biogas yield.

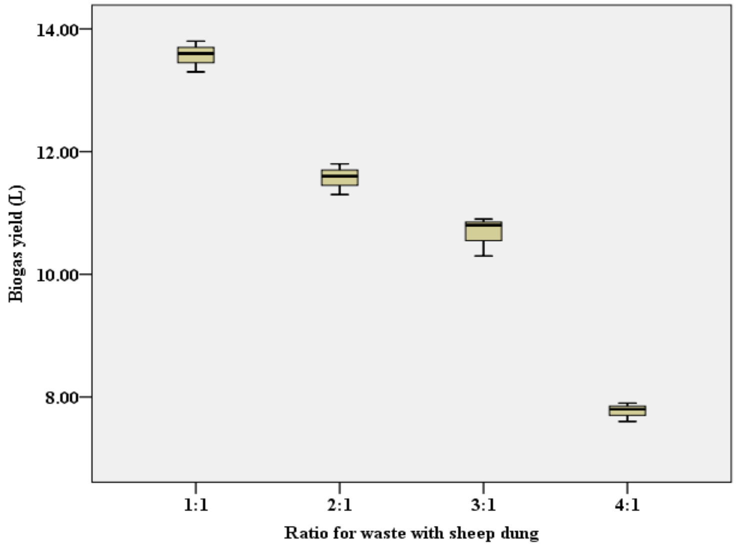

Figure 3. Effect of different mixing ratios of waste and sheep dung on average biogas yield

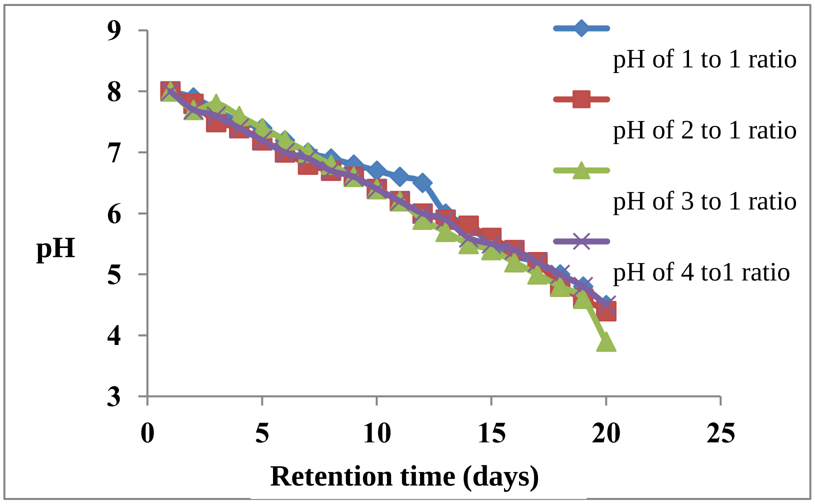

Figure 4. Variation of pH during the digestion period of waste with donkey dung in each ratio

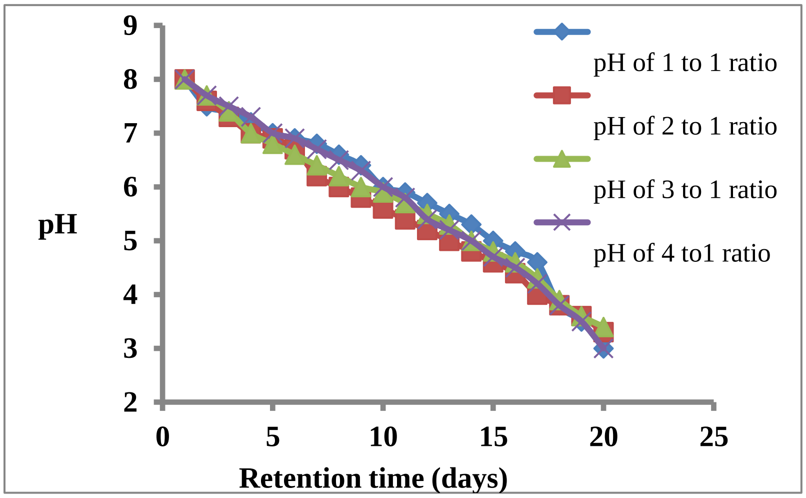

Figure 5. Variation of pH during the digestion period of waste with sheep dung in each ratio

3.5. Effects of digestion time on daily average biogas yield

In this study, the measurement of the daily average biogas yield waste with donkey dung and sheep dung in all digester biogas production started on the 6th day and reached its apex on the 20th day as shown in Figure 6 and Figure 7, and the results agree with Adelekan & Bamgboye, (2009) and Alkhamis et al., (2021). This length of the days to get biogas on the onset of the digestion period because it takes time for the substrate to decompose and generate biogas; the production of the biogas is directly related to the specific growth of methanogenic bacteria (Sagagi et al., 2009; Ngan et al., 2020). As shown in Figure 6, the average biogas measurement waste with donkey dung in all ratios started on Day 6 by producing a minimum amount in a little difference of each ratio. Thereafter, the amount of the average biogas yield increased day-to-day in all ratios. On Day 13, the maximum amount of the average biogas yield was obtained that 1:1 (2.5 L), 2:1 (2.5 L), 3:1 (2.25 L), and 4:1 (2 L). After Day 14, the production of biogas started to reduce day-to-day in all digesters. This finding indicates that all substrates in the digesters have been consumed, and biogas production was almost zero (Narayani and Priya, 2012; Nagy et al., 2019). As shown in Figure 7, average biogas measurements for waste containing all ratios of sheep manure started on day 6, with the smallest amount produced with a slight difference from each ratio. Thereafter, the amount of average biogas yield increased day-to-day in all ratios. On Day 15, the maximum amount of average biogas yield with the ratio of 3:1 (1.7 L), and 4:1 (1.4 L) was obtained. On Day 16, the maximum amount of average biogas yield with the ratio of 1:1 (2 L) and 2:1 (1.5 L).was obtained After Day 15 (ratio 3:1 and 4:1) and Day 16 (ratio 1:1 and 2:1), the production of biogas started to reduce day-to-day in all digesters. This finding indicates that all substrates in the digesters have been consumed, and biogas production was almost zero (Sawyerr et al., 2019).

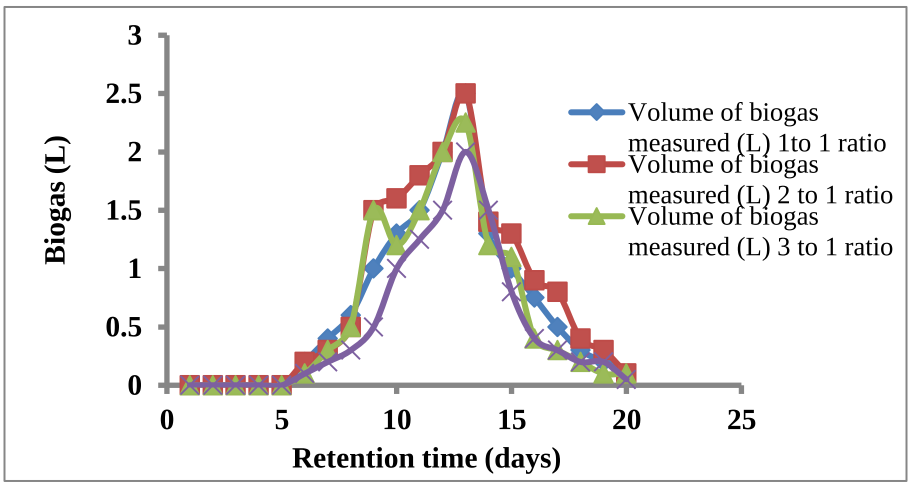

Figure 6. Measurement of daily average biogas yield with digestion time of calabash waste & donkey dung mixture

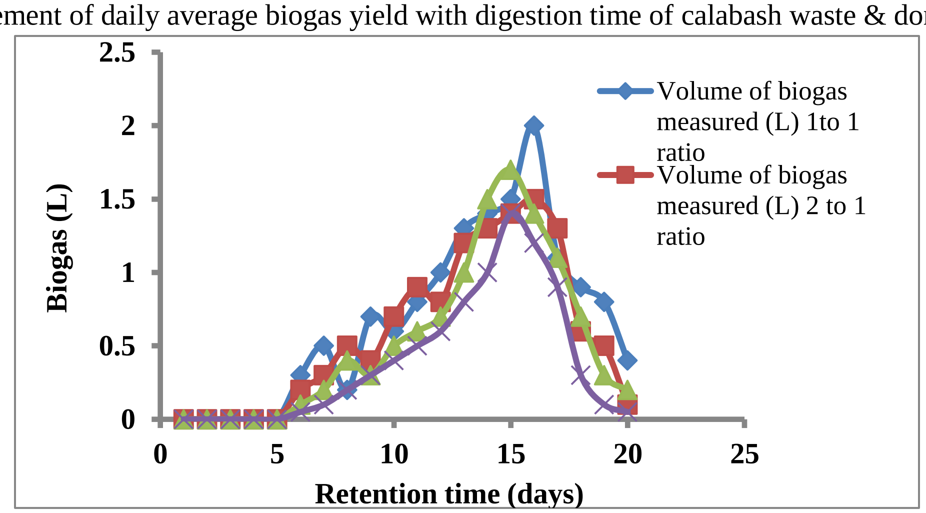

Figure 7. Measurement of daily average biogas yield with digestion time of calabash waste & sheep dung mixture

3.6. Biogas combustibility & volume measurement

The combustibility of the biogas generated in all digester ratios was tested with a match placed at the mouth of the gas outlet. The measurement of the volume of biogas generated by the water displacement method was done on the 6th-20th days of the start of digestion. The measurement was run in triplicate to see the reproducibility of the result, and a combustibility test was done for each measurement (Itodo et al., 1995; Mukumba et al., 2016). The gas produced was seen to burn with a blue flame on the 6th day since the onset of digestion. The gas generated from waste mixed with donkey dung had a relatively stronger blue flame than waste mixed with sheep dung (Alkhamis et al., 2021).

4. Conclusion

The result of this research on the Comparison of biogas productivity of calabash waste mixed in selected ratios with sheep and donkey dung has shown that flammable biogas can be produced from each ratio through anaerobic digestion. From this, it was observed that the strength of produced flammable biogas was different for each ratio. Slurries containing calabash waste with donkey dung produced more average biogas than the corresponding mixing ratios of calabash waste with sheep dung. Of all ratios, the mixture of 1:1 mass produced the highest biogas, while the mixture of 4:1 mass produced the least biogas in both dungs. Thus, a 1:1 ratio means the amount of calabash waste with dung (both donkey and sheep dung) equal amounts and enhances the anaerobic fermentation process. This enhancement was because dungs contain fermentative bacteria and free lignin materials. On the other hand, 4:1 means that the amount of waste has higher than the number of dung with proportion to this waste has bulky and accumulates some lignin relatively dung this leads retardation of the anaerobic fermentation process and decreases the number of biogas yields.

Recommendation

This study recommends mixing sheep and donkey dungs with calabash waste in the ratio of 1:1 by mass intended for biogas production from methane-generating systems., Calabash waste mixed with donkey dung in a ratio of 1:1 by mass is found to be a better alternative for the enhancement of biogas yield.

Data Availability

All the necessary information required for replication of this work and/or conducting secondary analysis is included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would thank to the Department of Chemistry, Industrial chemistry, and biology for the providing of ideas and necessary materials for fulfillment of the research work, Bahir Dar University, Ethiopia.

Authors' Contributions

TTM, MAM and FKS have identified the concept of the study problem together, and we have all taken part in collecting samples, preparing the experiment, compilation of the data for the first draft of the manuscript, analysing the data, and writing the first draft of the manuscript. We have also participated in the experimental work, checked the write-up, and critically reviewed the manuscript. There is no conflict of interest among the authors and we have approved the manuscript without any conflict of interest.

Reference

Abubakar, A., A. Zuru, I. Magali and T. Abubakar (2004). Biogas production from onion bulbs. Nig. J. Renewable Energy. Sokoto Energy Research Centre, Energy Commission of Nigeria, Usmanu Danfodiyo University, Sokoto 12(1): 2.

Adelekan, B. and A. Bamgboye (2009). Comparison of biogas productivity of cassava peels mixed in selected ratios with major livestock waste types. *Afr. J. Agric. Res., 4*(7): 571-577.

Adelowo, F. E. and S. O. Oladeji (2016). Spectrophotometric analysis of phosphate concentration in agricultural soil samples and water samples using molybdenum blue method. *Braz. J. Biol., 3*(6): 407-412.

Al Mamun, M. R. and S. Torii (2014). Production of Biomethane from Cafeteria, Vegetable and Fruit Wastes by Anaerobic Co digestion Process. *J. Adv. Agric. Technol., 3*(5)*:321-325*

Alkhamis, T. M., A. I. Alzoubi and B. M. Alma'atah (2021). Biogas Production from Sheep Manure by a Simulated Underground Burial System Heated with Cascade-Controlled Solar Water Heated System, as an Indicator of Biomass Potential Contribution to Power Mix in Jordan. *J. Environ. Prot., 12*(02): 125.

Arrhenius, K., A. Fischer and O. Büker (2019). Methods for sampling biogas and biomethane on adsorbent tubes after collection in gas bags. *Appl. Sci., 9*(6): 1171.

Audu, I. G., A. Barde, O. M. Yila, P. A. Onwualu and B. M. Lawal (2020). Exploring biogas and biofertilizer production from abattoir wastes in Nigeria using a multi-criteria assessment approach. *Recycl., 5*(3): 18.

Bahr, M., I. Díaz, A. Dominguez, A. Gonzalez Sanchez and R. Muñoz (2014). Microalgal-biotechnology as a platform for an integral biogas upgrading and nutrient removal from anaerobic effluents. *Environ. Sci. Technol., 48*(1): 573-581.

Banerjee, P. and B. Prasad (2020). Determination of concentration of total sodium and potassium in surface and ground water using a flame photometer. *Appl. Water Sci., 10*(5): 1-7.

Baum, R. L., W. Z. Savage and J. W. Godt (2002). TRIGRS—a Fortran program for transient rainfall infiltration and grid-based regional slope-stability analysis. US geological survey open-file report 424: 38. https://doi.org/10.3133/ofr20081159

Carcelon, J. and J. Clark (2002). Methane Biogas from Anaerobic Digesters. The US Environmental Production Agency, the US Department of Agriculture and the US Department of Energy: 64-68.

Chellapandi, P. (2004). Enzymes and microbiological pretreatments of oil industry wastes for biogas production in batch digesters., Pathade GR and Goel PK (Eds.) *Biotechnology and Environmental Management*. Jaipur, ABD Publishers.

Choi, Y., J. Ryu and S. R. Lee (2020). Influence of carbon type and carbon to nitrogen ratio on the biochemical methane potential, pH, and ammonia nitrogen in anaerobic digestion. *J. Anim. Sci. Technol., 62*(1): 74.

Fagerstedt, K. V., P. Saranpää, T. Tapanila, J. Immanen, J. A. Alonso Serra and K. Nieminen (2015). Determining the composition of lignins in different tissues of silver birch. *Plants 4*(2): 183-195.

Faizal, M., Y. Wardah, M. Husna, A. Amirah and Y. Tan (2018). Energy, economic and environmental impact of waste-to-energy in Malaysia. *J. Mech. Eng. Res. Dev., 41*: 109-113.

Gates, R., H. Xin, K. Casey, Y. Liang and E. Wheeler (2005). Method for measuring ammonia emissions from poultry houses. *J. Appl. Poult. Res., 14*(3): 622-634.

Gemechu, F. K. (2020). Evaluating the potential of domestic animal manure for biogas production in Ethiopia. *J. Energy* (1) :1-4.

Getahun, T., M. Gebrehiwot, A. Ambelu, T. Van Gerven and B. Van der Bruggen (2014). The potential of biogas production from municipal solid waste in a tropical climate. *Environ. Monit. Assess., 186*(7): 4637-4646.

Guarino, G., Carotenuto, F. Di Cristofaro, S. Papa, B. Morrone and M. Minale (2016). Does the C/N ratio really affect the Bio-methane Yield? A three years investigation of Buffalo Manure Digestion. *Chem. Eng. Trans.,* 49: 463-468.

Hicks, T. D., C. M. Kuns, C. Raman, Z. T. Bates and S. Nagarajan (2022). Simplified Method for the Determination of Total Kjeldahl Nitrogen in Wastewater. *Environments 9*(5): 55.

Ighravwe, D., O. Babatunde, O. Adedoja and T. Okharedia (2018). Evaluation and selection of hybrid renewable energy systems for healthcare centres in rural areas: a techno-economic approach. 2018 IEEE 7th International Conference on Adaptive Science & Technology (ICAST), IEEE.

Itodo, I., C. Onuh and B. Ogar (1995). Effect of various total solid concentration of cattle waste on biogas yield. *Nig. J. Renewable Energy* 13: 36-39.

Jijai, S., S. Muleng and C. Siripatana (2017). Effect of dilution and ash supplement on the bio-methane potential of palm oil mill effluent (POME). *AIP Conference Proceedings*, 1868, 020013, AIP Publishing LLC.https://doi.org/10.1063/1.4995099

Jos, B., F. Hundagi, R. P. Wisudawati and S. Sumardiono (2018). Study of C/N ratio effect on biogas production of carica solid waste by SS-AD method and LS-AD. *MATEC. Web. Conf.,* 156: 03055, https://doi.org/10.1051/matecconf/201815603055

Koch, K., B. Helmreich and J. E. Drewes (2015). Co-digestion of food waste in municipal wastewater treatment plants: effect of different mixtures on methane yield and hydrolysis rate constant. *Appl. Energy*, 137: 250-255.

Kumar, N., G. Dureja and K. Sandeep (2014). To make a biogas energy from different sources & creating awareness between human begins—case study. *Int. J. Mod. Eng. Res. Technol.,* 4(3): 1510-1516.

Liu, X., J. Yang, T. Ye and Z. Han (2018). Establishment of analysis method for methane detection by gas chromatography. I*OP Conference Series: Earth Environ. Sci.,*, IOP Publishing 113:012023

Miah, M. R., A. K. M. L. Rahman, M. R. Akanda, A. Pulak and M. A. Rouf (2016). Production of biogas from poultry litter mixed with the co-substrate cow dung. *J. Taibah Univ. Sci.,* 10(4): 497-504.

Mukumba, P., G. Makaka and S. Mamphweli (2016). Anaerobic digestion of donkey dung for biogas production. *S. Afr. J. Sci.*, 112(7-8): 1-4.

Mulat, D. G. and S. J. Horn (2018). Biogas production from lignin via anaerobic digestion. Gregg T Beckham (Ed.) *Lignin Valorization: Emerging Approaches, Energy and Environment* (pp391-412): Royal Society of Chemistry

Muzenda, E. (2014). Bio-methane Generation from Organic Waste: A. *Proceedings of the world congress on engineering and computer scienc*e 2: 647-652

Nagy, G., A. Takács and A. A. Kállay (2019). The energy aspects of biogas production from sheep manure. *Carbon* 29: 37-70.

Narayani, T. and P. G. Priya (2012). Biogas production through mixed fruit wastes biodegradation. *J. Sci. Ind. Res.*, 71(3): 2017-220

Nevzorova, T. and V. Kutcherov (2019). Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Rev.*, 26: 100414.

Ngan, N. V. C., F. M. S. Chan, T. S. Nam, H. V. Thao, M. C. Maguyon-Detras, D. V. Hung, D. M. Cuong and N. V. Hung (2020). Anaerobic digestion of rice straw for biogas production. Martin, G., Nguyen, V.H., Pauline, C., Boru, D. (Eds.) *Sustainable Rice Straw Managemen*t (pp65-92): Springer Cham

Nwagbo, E., I. Dioha and M. Gulma (1991). Qualitative investigation of biogas from Cow and Donkey dung. *Nig.J. Sol. Energy* 10: 145-149.

Orhorhoro, E. K., P. O. Ebunilo and G. E. Sadjere (2017). Experimental determination of effect of total solid (TS) and volatile solid (VS) on biogas yield. *Am. J. Mod.Energy* 3(6): 131-135.

Peces, M., S. Astals and J. Mata-Alvarez (2014). Assessing total and volatile solids in municipal solid waste samples. *Environ. Technol.*, 35(24): 3041-3046.

Piątek, M., A. Lisowski and M. Dąbrowska (2021). The effects of solid lignin on the anaerobic digestion of microcrystalline cellulose and application of smoothing splines for extended data analysis of its inhibitory effects. *Bioresour.Technol.*, 320: 124262.

Rai, M. and S. S. Da Silva (2017). Nanotechnology for bioenergy and biofuel production. Springer Nature. DOI: 10.1007/978-3-319-45459-7

Ryan, J., G. Estefan and A. Rashid (2001). *Soil and plant analysis laboratory manual.* International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

Sagagi, B., B. Garba and N. Usman (2009). Studies on biogas production from fruits and vegetable waste. *Bayero J. Pure Appl. Sci.*, 2(1): 115-118.

Sajeena, B., P. Jose and G. Madhu (2013). Effect of total solid concentration on anaerobic digestion of the organic fraction of municipal solid waste. *Int. J. Sci. Res. Publ.*, 3(8): 1-5.

Sawyerr, N., C. Trois, T. Workneh and V. I. Okudoh (2019). An overview of biogas production: Fundamentals, applications and future research. *Int. J. Energy Econ. Policy* 9(2), 105-116

Shane, A. and S. H. Gheewala (2017). Missed environmental benefits of biogas production in Zambia. *J. Clean. Prod.*, 142: 1200-1209.

Siraj, K. and S. A. Kitte (2013). Analysis of copper, zinc and lead using atomic absorption spectrophotometer in ground water of Jimma town of Southwestern Ethiopia. *Int. J. Anal. Chem.*, 4(4): 201-204.

Siswanti, D. U., U. Utaminingsih, M. F. Lestari and H. Hamdian (2019). Application of Bio Fertilizer and Biogas Sludge to Curly Red Chili (Capsicum annuum L.) at Wukirsari Village, Cangkringan, Sleman. *Jurnal Pengabdian kepada Masyarakat (Indonesian Journal of Community Engagement)* 5(3): 371-387.

Sluiter, A., B. Hames, D. Hyman, C. Payne, R. Ruiz, C. Scarlata, J. Sluiter, D. Templeton and J. Wolfe (2008). Determination of total solids in biomass and total dissolved solids in liquid process samples. *National Renewable Energy Laboratory* 9: 1-6.

Sluiter, A., B. Hames, R. Ruiz, C. Scarlata, J. Sluiter, D. Templeton and D. Crocker (2008). Determination of structural carbohydrates and lignin in biomass. *Laboratory analytical procedure* 1617(1): 1-16.

Sorathia, H. S., P. P. Rathod and A. S. Sorathiya (2012). Bio-gas generation and factors affecting the bio-gas generation–a review study. *Int. J. Adv. Eng. Technol.*, 3(3): 72-78.

Sreekrishnan, T., S. Kohli and V. Rana (2004). Enhancement of biogas production from solid substrates using different techniques—a review. *Bioresour. Technol.*, 95(1): 1-10.

Syaichurrozi, I. and S. Sumardiono (2014). Effect of Total Solid Content to Biogas Production Rate from Vinasse (RESEARCH NOTE). *Int. J. Eng.*, 27(2): 177-184.

Tsapekos, P., P. Kougias, L. Treu, S. Campanaro and I. Angelidaki (2017). Process performance and comparative metagenomic analysis during co-digestion of manure and lignocellulosic biomass for biogas production. *Appl. Energy* 185: 126-135.

Tuzen, M., A. Onal and M. Soylak (2008). Determination of trace heavy metals in some textile products produced in Turkey. *Bull. Chem. Soc. Ethiop.*, 22(3).

Victor, Y., L. Sriwuryandari, E. Priantoro, T. Sembiring and N. Sintawardani (2018). Influence of pH on biogas production in a batch anaerobic process of tofu wastewater. *IOP Conference Series: Earth and Environmental Science, IOP Publishi*ng 160:012014

Wang, Z. and L. Geng (2015). Carbon emissions calculation from municipal solid waste and the influencing factors analysis in China. *J. Clean. Prod.*, 104: 177-184.

Yaru, S., K. Adewole and I. Adegun (2014). Comparative study of biogas from cattle dung and mixture of cattle dung with plantain peels. *Nig. J. Technol. Res.*, 8(2): 44-49.

Zhang, Q., J. Zhang, S. Zhao, P. Song, Y. Chen, P. Liu, C. Mao and X. Li (2021). Enhanced biogas production by ligninolytic strain Enterobacter hormaechei KA3 for anaerobic digestion of corn straw. *Energie*s 14(11): 2990.