Building Smart, Resilient and Sustainable Infrastructure in Developing Countries – Musonda & Mwanaumo (eds)

Biogas production potential from co-digestion of composted faecal sludge mixed with rice husks and sawdust

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ABSTRACT: The global demand for energy is increasing, with 80% of total energy obtained from fossil fuels rich in greenhouse gases. Biogas is an effective alternative to fossil fuels. Thus, this study aimed at evaluating biogas production potential from co-digestion of composted faecal sludge (FS) mixed with rice husks (RH) and sawdust (SD). FS of 2000g, 3000g was mixed with RH and SD (2mm, 4mm). The ratios for RH and SD were 1:0, 0:1, 1:1, 3:1, 1:3; each mixed with FS, composted for 20days followed by biogas production. Quantity and quality of biogas were measured using water and NaOH displacements, respectively. CH_4 content ranged between 74-76%. Digester with 2000g FS and 100g RH (4mm) performed excellently, producing 17.2L of biogas. Conclusively, RH, SD and FS have potential to produce biogas. However, a comparative study should be done on fresh and composted materials to assess the influence of composting on biogas production.

Keywords: Biogas, Composting, Faecal-Sludge, Rice-husks, Sawdust

1 INTRODUCTION

Globally, 80% of the energy consumed comes from fossil fuels (Ritchie *et al*, 2020). Specifically, in developing countries, 91% of the population entirely depends on the use of biomass consisting of firewood, charcoal, straw and some crop residues as a source of fuel energy for different purposes (Sawyerr *et al.*, 2019). Fossil fuels pose several negative impacts on the environment including air pollution, environmental degradation and health problems such as skin disease and lung cancer (Sawyerr *et al.*, 2019). Also, faecal sludge has been causing serious effects on human health such as the breakout of deadly diseases including cholera and

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DOI: 10.1201/9781003325321-1

typhoid, which is the result of poor sludge management systems like the use of pit latrines. The world's sludge production rate is estimated to be around 45 million dry tons per year *(Karlikanovaite-balikci et al.*, 2019).

Sewage sludge production is expected to increase due to the highly increasing number of populations (Abdel-shafy & Mansour, 2018). Faecal sludge tends to be disposed of improperly, sometimes into the water systems such as rivers which then contribute to the spread of diseases like cholera, diarrhoea and typhoid (Lindberg & Rost, 2018). Thus, the conversion of sewage sludge into useful products is important whereby it can be utilized as a feedstock for biogas production which is a renewable and environmentally friendly source of energy, therefore, solving the problem of energy crisis and fossil fuels while conserving the environment (Agani *et al.*, 2017).

Furthermore, sawdust and rice husks are other common and mostly produced wastes in the environment (Akowuah *et al.*, 2017). Sawdust results from woodworking operations such as sawing, milling, routing, drilling, and sanding. It is composed of small particles of wood that are hazardous to human health, and when inhaled leads to respiratory problems (Akowuah *et al.*, 2017). Rice is the world's third-biggest yield behind maize and wheat and the waste item additionally positions as the world's third-biggest rural residue (Korotkova *et al.*, 2016). Both sawdust and rice husks are the most abundant agricultural residues and they do not tend to easily undergo decomposition by micro-organisms because of their high lignin content composition; due to that, they accumulate in the environment forming a pile producing anoxic condition (Korotkova *et al.*, 2016). These piles have the potential to harbour disease-causing microorganisms such as bacteria and fungus. The materials are usually burnt and sometimes dumped into the environment which then results in the production of greenhouse gases including carbon dioxide and methane that pollute the atmosphere (Azura *et al.*, 2018). However, the two materials contain high content of cellulose which makes them suitable and potential for anaerobic digestion hence becoming the most important source of renewable energy that is a substitute to fossil energy reducing the emission of greenhouse gases such as carbon dioxide into the atmosphere (Wang *et al.*, 2016).

Several studies have been conducted on biogas production by using different substrates such as fruits wastes, poultry and piggery wastes, and cassava peels with cow dung as inoculum (Olukanni et al., 2022; Olukanni and Ojukwu, 2022; Fagbenle and Olukanni, 2021). However, the potential of resource recovery by using rice husk and sawdust with faecal sludge is still being explored. For instance, Karne *et al.*, (2018) did a study on biogas production from faecal sludge at a different temperature ranging for mesophilic (25ºC-45ºC) and thermophilic (50ºC-60ºC). The biogas production rate ranged between 0.06 to 0.12 m^3 per kg of dry mass per day at mesophilic conditions while at the thermophilic conditions the production rate ranged between 0.1–0.21 m^3 per kg of dry mass per day. On the other hand, Syafrudin *et al.*, (2020) conducted research on biogas production enhancement from rice husks pre-treated by NaOH and enzyme, and found out that the pre-treated rice husks using 6% NaOH produced 497ml of biogas while the production using 11% enzyme was 667.5ml with the pre-treated rice husks using 11% enzyme. Matin & Hadiyanto, (2018), also conducted a study on biogas production using rice husk pre-treated with 3% NaOH and reported the highest biogas yield as 63.93ml/g TS. Similarly, Zumalla *et al.*, (2018) performed a study on production of biogas from sawdust pre-treated with 4% NaOH and found the highest production of 709 ml/g per day. However, the study on co-digestion of two lignocellulosic materials, rice husks and sawdust pre-treated with natural method (i.e., composting) with addition of faecal sludge has been rarely investigated.

Therefore, this study aimed at converting these readily available and highly produced environmental wastes (faecal sludge, rice husks and sawdust) into a most useful form of energy (biogas) that is renewable and environmentally friendly through composting (pretreatment) and anaerobic digestion. Hence solving environmental pollutions caused by improper waste management while recovering resources for energy production.

2 MATERIALS AND METHODS

This study was carried out at Ardhi University in Dar es Salaam – Tanzania. The methods used in this study involved experimental setups and laboratory analysis. The major raw materials used in this study were rice husks, sawdust and faecal sludge. The rice (Oryza Sativa) husks were obtained from the local grinding machine in Dar es Salaam and sawdust was purchased from Mwenge carpentry Centre in Dar es Salaam. The faecal sludge was obtained from septic tanks used at Ardhi University

2.1 *Experimental setup*

2.1.1 *Composting*

The in-vessel composting method was used during composting as described by *Manyapu et al.*, (2017). The composter was made of a plastic bottle with a capacity of 12 litres. The experiment was divided into four runs (groups A2, A4, B2 and B4) based on variation in the quantity of faecal sludge (FS) and particle size of the materials (rice husks (RS) and sawdust (SD). Each run contained five sets of experiments based on the mixing ratios. In each experimental run the amount of faecal sludge was kept constant (2000g or 3000g) but the variation was based on the amount of rice husks and sawdust (250g, 500g, 750g, and 1000g) and their particle sizes (2mm and 4mm). Faecal sludge was mixed with rice husks and sawdust at 5 different ratios (1:0, 0:1, 1:1,1:3, and 3:1) for each particle's size making a total of 20 compost bins. The weight of materials was measured by using a weight balance of 100kg capacity. The materials in each compost bin were well mixed to attain homogeneity and allow aeration of the compost. The temperature was monitored daily while pH and moisture content monitoring were done after every four days for 20 days.

2.1.2 *Biogas production*

The biogas production was carried out in a batch reactor system, consisting of 20 reactors systems. The batch reactor system was made of a 6-litre plastic bottle digester containing feedstock materials (composted rice husk, sawdust and faecal sludge). A 1.2 litre invented plastic bottle full of water (gas collection unit). About 0.5 meters in length and 7mm inner diameter hose pipe for conveying gas from the digester to the gas collector. A 1-litre plastic bottle (water collector). The composted materials were used for biogas production with the same mixing ratios used during composting. Before feeding the substrate 1250 ml of water was added to the specified weight of the compost, followed by 500ml (faecal sludge) seed material as shown in Table 1; and then mixed thoroughly to obtain homogeneity. The mixture was fed into the digester. The quantity and quality of the gas were measured daily using the water and sodium hydroxide displacement method, respectively. Ambient temperature was measured on daily basis. The measurement of substrate parameters was performed before feeding the material in the digesters and after anaerobic digestion process. The measured parameters were pH, chemical oxygen demand (COD) and total solids (TS) using the standard methods of analysis (2017).

2.2 *Data analysis and presentation*

All the results were analyzed and figured out using descriptive statistical analysis available in Microsoft Excel 2013 spreadsheet. The statistical comparison was performed using single-factor ANOVA and significant difference offset at $p<0.05$.

3 RESULTS AND DISCUSSIONS

3.1 *Composting*

Raw materials were characterized prior composting and the results are as indicated in Table 2. pH of raw materials ranged from 6.1 to 7.1 in rice husks while faecal sludge had pH of 7.5.

Table 1. The amount of the materials added to the digester, amount of seed material used and volume of water added to the mixture to form slurry.

Exp run	Particle size	Rice husks (g)	Sawdust (g)	Optimized ratios, w/w	Reactor Name	Compost fed in the reactor (g)	Seed material (FS)(g)	Volume of H_20 added (ml)
2000g Faecal sludge								
A2	2mm particle size	1000	0	R_1(1:0)	A_2R_1	2000	500	1250
		0	1000	R_2(0:1)	A_2R_2	2000	500	1250
		500	500	R_3(1:1)	A_2R_3	2000	500	1250
		750	250	R_4(3:1)	A_2R_4	2000	500	1250
		250	750	R_5(1:3)	A_2R_5	2000	500	1250
A4	4mm particle size	1000	0	R_1(1:0)	A_4R_1	2000	500	1250
		0	1000	R_2(0:1)	A_4R_2	2000	500	1250
		500	500	R_3(1:1)	A_4R_3	2000	500	1250
		750	250	R_4(3:1)	A_4R_4	2000	500	1250
		250	750	R_5(1:3)	A_4R_5	2000	500	1250
3000g Faecal sludge								
B2	2mm particle size	1000	0	R_1(1:0)	B_2R_1	2000	500	1250
		0	1000	R_2(0:1)	B_2R_2	2000	500	1250
		500	500	R_3(1:1)	B_2R_3	2000	500	1250
		750	250	R_4(3:1)	B_2R_4	2000	500	1250
		250	750	R_5(1:3)	B_2R_5	2000	500	1250
B4	4mm particle size	1000	0	R_1(1:0)	B_4R_1	2000	500	1250
		0	1000	R_2(0:1)	B_4R_2	2000	500	1250
		500	500	R_3(1:1)	B_4R_3	2000	500	1250
		750	250	R_4(3:1)	B_4R_4	2000	500	1250
		250	750	R_5(1:3)	B_4R_5	2000	500	1250

Organic matter ranged from 41.5 to 54, 22.4% in sawdust and 61.5% in faecal sludge, showing potential of these materials in biogas production. A study done by Afifah & Priadi, (2017) indicated similar results.

Table 2. Physical characteristics of raw materials used in the experiment.

Type of waste	pH	Moisture content (%)	Total solids (%)	Volatile solids (%)	Organic matter (%)
Faecal sludge	7.5	79	21	36.2	64.5
Rice husks (4mm)	7.1	10.7	89.3	53.4	41.5
Rice husks (2mm)	6.1	26	74	73.7	54
Sawdust	7.3	31	69	51	22.4

3.1.1 *Temperature profile and its effect on composting*

It was observed that on the first day of composting the temperature of the mixture was reading the same as the room temperature. On the fourth day, the temperature started rising and the maximum temperature was observed to be 54.5°C and 53.5°C in reactors A_2R_4 and A_2R_2, respectively. On day 6, the higher readings were observed in reactor B_2R_1 and B_2R_4 which was 57.3°C and 49.4°C, respectively. The lowest readings were observed in reactors A_4R_4 (30°C) and B_4R_2 (32°C) while the temperature was moderate for the other reactors. The temperature rise indicates the active phase of composting that involves growth of microorganisms and decomposition of organic matter (Lalremruati & Devi, 2021). From day 8, the temperature for all reactors started to gradually decrease until it reached 26.6°C which was the same as the room temperature. The decrease in temperature indicates the presence of small or no organic content available for microorganisms (Otaraku & Ogedengbe, 2013). Thus, the temperature for all reactors ranged between 26.6°C and 57.3°C throughout the composting period. Azura *et al.*,(2018) performed the composting of rice straw and food waste under the temperature range of 22°C to 50°C which is also similar to the findings of the current study.

3.1.2 *pH level monitoring*

pH of the compost from all reactors ranged from 4.8 to 8.0 during the whole period of composting. The results show that there was a drop in pH at the initial stage of composting which was observed on day 4, pH decreased to the range of 4.8 to 5.5; this was because the initial stage of composting involves the formation of organic acids that lower the compost pH; followed by ammonification which causes the rise in pH (Azura *et al.*, 2018; Lalremruati & Devi, 2021) and it was observed from day 8 to day 12 in which the pH range rose to 7.3-8.0. This pH range is suitable for the mesophilic and thermophilic bacteria (Lalremruati & Devi, 2021); thus, it facilitates the fast decomposition of organic matter. The pH is then adjusted to near neutral (6.8-7.1) on the last days of composting (from day 15 to 20) which is the indication of complete composting and compost maturity. The decrease in pH at the initial stage of composting reflects the one reported by Sharma & Yadav, (2017) in their study about the conversion of flower waste into organic compost. However, the pH of the compost for all the reactors performed within a suitable range for microbial activities, that is between 5.5 to 8.0 as recommended by Ameen *et al.*, (2016).

3.1.3 *Moisture content*

There was a variation in moisture content for all the compost bins due to the dry nature of the materials contained and quantity of faecal sludge added, the highest moisture content value was 56.4% as observed in reactor A_2R_1 contained with rice husks and faecal sludge and the minimum value was 33.4% observed in reactor B_4R_2 contained with sawdust and faecal sludge while other reactors show a moderate moisture value Based on the study done by Azura*et al.*, (2018) the optimum moisture content for composting should range from 40 to 60%. However, in the current study, the water was added to the compost to adjust moisture content, it then ranged from 41.1% to 57.3% which is within the recommended range for effective material degradation.

3.2 *Biogas production*

3.2.1 *Characterization of the substrate*

The lowest value of pH was 6.75 while the highest was 7.6 for reactor A_2R_5 and A_2R_1, respectively. The pH was within the optimum range for all digesters from the fact that the optimum pH for anaerobic digestion ranges between 6 and 8 as recommended in the previous studies (Ameen*et al.*, 2016). pH is the vital parameter for the growth of anaerobic bacteria that are responsible for biogas production (Paramaguru *et al.*, 2017).The minimum total solids obtained was 16.4 % in reactor A_2R_1 while the highest number of total solids was 35.5% in reactor A_2R_4. This was contributed by the fact that the amount of water added to the substrate was uniform despite the fact that some of the substrates had low moisture content. Orhorhoro *et al.*, (2017) reported the optimum total solids for anaerobic digestion ranging from 10-25% is suitable for the performance of methanogenic bacteria.

The concentration of COD ranged from 2030mg/L in reactor B_4R_5 to 9220mg/L in reactor A_4R_1. The higher COD in reactor A_4R_1 was contributed by the effectiveness of the performed composting in reduction of the inhibiting factors for bacterial degradation that is cellulose and lignin present in rice husks and sawdust. While the composting in reactor B_4R_5 was observed to be poor because, it didn't achieve its aim of removing cellulose and lignin content of the material as a result the biodegradable content of the material remained small, causing low COD concentration.

The highest temperature was measured on day 3 and the minimum temperature was measured on day 13 which were 31°C and 25.2°C respectively. The fluctuation in ambient temperature was due to changes in weather conditions. The favourable temperature for the anaerobic digestion process ranges from 28°C to 37°C (Schnaars, 2012). Temperature facilitate degradation of the organic matter and hence fast biogas production rate (Babaei & Shayegan, 2020).

3.2.2 *Biogas production rate*

3.2.2.1 Biogas production rates from reactors A2 (FS, 2000g; RH and SD particle size, 2mm)

The biogas production from all reactors in this cradual increase in production from day 1 to day 7. The increase in production was influenced by the presence of high organic content and fully adaptation of the bacteria to the environment (Gummert *et al.*, 2020). From day 8 to day 21 the biogas production decreased and from day 22 to 26 there was no production of gas. At this stage, there was no longer organic content or nutrients available for the functioning and growth of microorganisms (Otaraku & Ogedengbe, 2013).

The reactor A_1R_1 was observed to produce a higher volume of biogas on days 1, 2,4 and on day 5 where the production was at its peak. It produced total biogas of 11463mls for 26 days of anaerobic digestion. The high biogas production rate was influenced by suitable conditions in the reactor such as pH which was 7.6 and mesophilic temperature as well as a high concentration of organic matter in terms of COD (8840 mg/l), the reactor conditions were similar to the study done by Schwartz *et al.*, (2015) on biogas production using co-digestion of food waste and algal biomass operating under pH range of 6 to 7.8 and mesophilic temperature range between 22°C and 30.5°C. While the reactor A_2R_4 was observed to perform poorly since day 1 and produced a least total biogas of 2609mls. The poor performance is probably because it contained higher total solids,35%, which was above the recommended range (15% to 28%), as reported by Orhorhoro *et al.*, (2017), the high concentration of solids indicates the low volume of water in the material, as a result it decreases the level of microbial activity, hence cause drop in biogas production. The higher total solids provide unsuitable conditions for microbes to digest the wastes (Orhorhoro et al., 2017). The results from other reactors were found to be moderate ranging from 9000mls to 10381mls. These results can be compared with the one obtained by Length, (2011) who used millet and guinea corn husks for biogas production, he found that the highest biogas volume on day 14 (2240cm^3) and the least on day 30 (1820 cm^3).This study achieved the highest volume (2100mls) on day five of anaerobic digestion (AD) and this was because of the immediate production of the biogas at the start of experiment which was influenced by the composting performed before AD that made it easier for bacteria to digest the feedstocks (Gummert *et al.*, 2020).

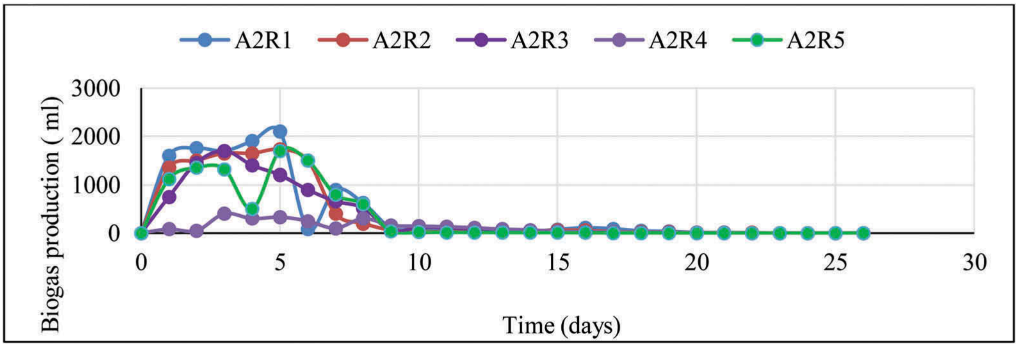

Figure 1. Biogas production rates for the reactors *A2 (FS, 2000g; RH and SD particle size, 2mm).*

3.2.2.2 Biogas production rate from reactors A4 (FS, 2000g; RH and SD particle size, 4mm)

Figure 2 shows that the biogas production rate from all reactors insting performed that reduced the concentration of cellulose and lignin that would inhibit the production of biogas (Mulyawan *et al.*, 2018). Production started decreasing from day 7 to day 10, this was possibly due to the decrease in temperature which was 27°C that is not suitable for mesophiles (Lalremruati & Devi, 2021). The production was no longer observed from day 22 to day 26 because all organic matter has already been converted to biogas. The reactor A_4R_1 was observed to produce larger quantity biogas (17202mls). This high production was influenced by the optimum pH and temperature that accelerate the microbial activity; however, this digester contained feedstock that had a higher concentration of organic matter in terms of COD. The lowest production was observed in reactor A_4R_2, possibly because of the lower concentration of organic matter (Olatunde, 2016). However, other reactors produced a moderate quantity of biogas which ranged from 1977mls to 1630mls.

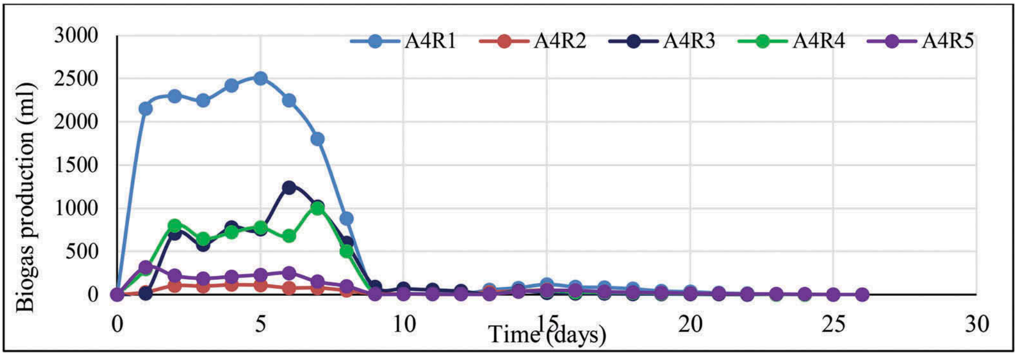

Figure 2. Biogas production rate from reactors A4 (FS, 2000g; RH and SD particle size, 4mm).

3.2.2.3 Biogas production rate from reactors B_2 (FS, 3000g; RH and SD particle size, 2mm)

The biogas production from these reactors started immediately at the beginning of the experiment, there was a high increase in production up to day 6. From day 7 the production from all reactors started to decrease (Figure 3). This might be due to the decrease in temperature from 28°C to 26°C which is not favourable for the thermophilic bacteria (Grand, 2017). The production kept decreasing up to day 23 which is the indication that the concentration of organic matter digestible by the microorganisms was decreasing Zupancic & Grilc (2012). From day 23 to 26 there was no more production of biogas since there were no more nutrients available for microorganisms (Otaraku & Ogedengbe, 2013). At this stage, all the organic content was already converted to biogas. The largest total biogas volume in this set of reactors was 9331mls, produced from the reactor B_2R_1. However, the minimum production was observed in reactor B_2R_4 which was 685mls for 26 days.

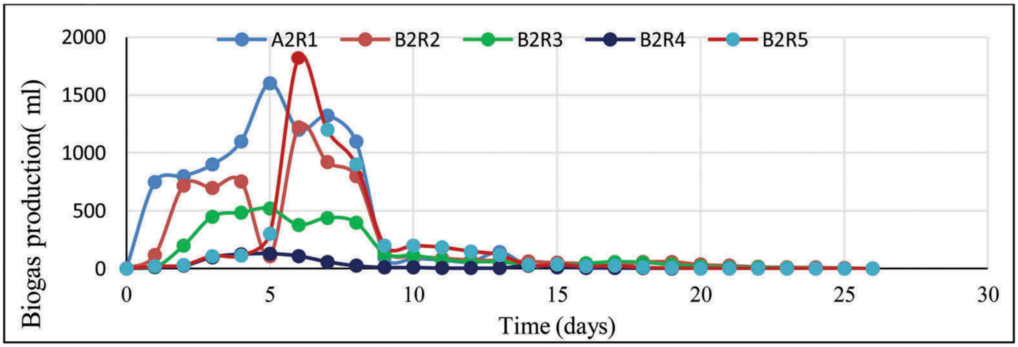

Figure 3. Biogas production rate from reactors B_2 (FS, 3000g; RH and SD particle size, 2mm).

3.2.2.4 Biogas production rate from reactors B_4 (FS, 3000g; RH and SD particle size, 4mm)

Figure 4 shows that the production of biogas started from day 1. There was high production from day 1 to day 7. From day 8 to day 19 the production started decreasing due to the reduction in organic content of the wastes by the microbes, similar decrease in production was observed by Jalil *et al.*, (2021) who performed study on biogas generation from vegetable wastes where he found that the production rate was high up to 3000mls from day 1, but it abruptly decreased to 750mls on 6^{th} day of operation. There was zero production from day 20 to 26, meaning that all organic content has already been consumed up and bacteria had no more nutrients to feed on to survive (Jalil *et al.*, 2021). Reactor B_4R_1 and B_4R_5 produced larger total volumes i.e., 7620mls and 8011mls, respectively while other reactors have produced a moderate quantity of biogas ranging from 4221mls to 7779mls.

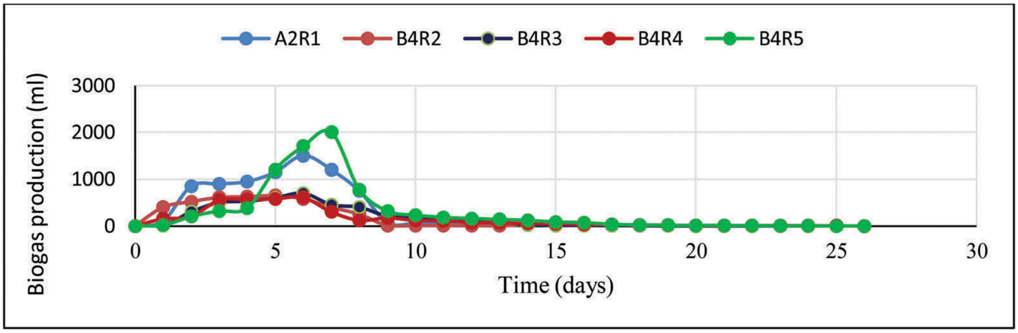

Figure 4. Biogas production rate from reactors B_4 (FS, 3000g; RH and SD particle size, 4mm).

3.3 *Overall biogas production*

It was observed that the reactor A_4R_1 produced a larger quantity of biogas, 17202mls in 26 days, followed by reactor A_2R_1 and A_2R_2 which produced 11463mls and 10381mls, respectively. The higher production in these reactors was probably influenced by co-composting performed being more effective in reduction of the inhibiting factors for anaerobic digestion such as cellulose and lignin (Mulyawan *et al.*, 2018). Also, the organic matter in terms of COD for these reactors, A_4R_1, A_2R_1 and A_2R_2 was found higher that is 9220mg/l, 8840mg/l and 6200mg/l, respectively. The higher COD indicates the presence of high organic content in the material that is consumed by anaerobes producing biogas (Isni *et al.*, 2016).On the other hand, reactor B_2R_4, A_4R_2, A_4R_5 and A_2R_4 produced a smaller quantity of biogas which was 685mls,1193mls, 1977mls and 2609mls, respectively. The low production in these reactors was due to the poor performance in co-composting, that is the composting was not effective in reducing cellulose and lignin contained in the material, rice husks and sawdust, hence they resist degradation by anaerobic bacteria, thus, poor production of the biogas. In addition to that, the reactors, B_2R_4, A_4R_2, A_4R_5 and A_2R_4 contained a low COD than 5020mg/l, 2240mg/l, 4250mg/l and 4300mg/l, respectively. The low COD is the indication of less organic content in the material, as a result the anaerobic bacteria dies after finishing up the degradable portion of the material, therefore this results to low production of the biogas (Isni *et al.*, 2016).

The production of biogas from the other reactors was found to be moderate ranging from 3851mls to 9331mls. Thus, from the experiment it can be concluded that, the best organic waste fraction, which produced a high amount of biogas is the one with 2000g of faecal sludge and 1000g of rice husks with a 4mm particle size (reactor A_4R_1).

3.4 *Quality of the produced biogas*

The lowest amount of methane produced was 74% while the highest amount was 76%. Carbon dioxide ranged from 26% to 24%. The methane content variations for all the reactors were very close to each other. This close variation was statistically proved using single factor ANOVA which shows that there is no significant difference in biogas quality between the waste fractions from all reactors ($p>0.05$). These results can be compared with the one obtained by Mechanization, (2019) in the study of co-digestion of fecal sludge with three different materials, cow dung, mixed organic wastes and cow intestinal, reported that the methane concentration ranged from (40-70%), carbon dioxide (20-30%) and H_2S (8-10%).

3.5 *COD reductions from different waste fractions*

The COD reduction for all reactors ranged from 42.3 to 79.7%. The maximum COD removal was observed in reactor A_4R_1 which was 79.7%. While the minimum COD reduction was observed in ratio B_2R_4, which was 42.3%. The reduction of chemical oxygen demand (COD) observed in this study agreed with (Mechanization, 2019) who reported that anaerobic digestion is a feasible way of reducing COD from sludge or wastewater. Similarly, the reduction in chemical oxygen demand in this study reflects the one reported by (Wei *et al*., 2011) who reported high COD removal from buoyant hydrothermally treated sewage sludge through an anaerobic digestion process. Furthermore, the exact same results were obtained by (Colón *et al*., 2015) in his study about anaerobic digestion of undiluted human excreta where he found that the process is 80% efficient for COD removal in such a way it could be used as a low-cost method for effective sanitation in developing countries.

4 CONCLUSION AND RECOMMENDATIONS

The current research tried to solve environmental pollution caused by improper solid waste management by recovering some potential resources including biogas production, and the study shows that it is feasible to produce biogas from the mixture of pre-composed rice husks, sawdust and faecal sludge for all the mixing ratios. The ratio which produced the highest amount of biogas was the one that contained with 2000g of faecal sludge and 1000g of rice husks with 4mm particle size (reactor A_4R_1) produced 17202mls of biogas for 26 days i.e., 661.7mls per day and achieved the highest 80% COD removal. Therefore, the ratio 1:0 of rice husks and sawdust with 4mm particle size and 2000g of faecal sludge was found to be the optimum ratio for biogas production. However, a comparative study should be done on fresh and composted organic wastes for a different composting period to assess the influence of composting on biogas quantity and quality production.

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