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Biogas Production from The Horse Dung

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Abstract
This study aims to identify the potentiality of biogas generation from the Horse dung in a batch digestor at the urban city of Kathmandu Valley. The experiment was performed at psychrophilic temperature zone of 21.3ºC ±1.3 ºC with dilution at 7% of Total Solids. On average, the percentage composition of methane was 52.48% and carbon dioxide was 36.26% throughout the study period. The maximum % composition of methane was observed to be 57.20% on the 11th May 2021 (i.e.12th Day of the Experiment) and minimum of 44.59% on the 2nd May 2021 (i.e.3rd day of the Experiment). Similarly, the % composition of carbon dioxide was maximum on the 2nd May 2021 and minimum on 20th June 2021. The favorable pH range of 6.5 to 7.5 for anaerobic digestion of biomass was observed within the range for 65.45% of the total experiment days. The % composition of methane content rises till the 12th day of the experiment and remains almost neutral till the end of the experiment while the carbon dioxide composition decrease with increase in methane composition and remains almost same until the end of the experiment. While, other gases composition slowly increases till the 12th day and just increases slightly and remain in the range as described in the literature. The volatile solids decrease from 3160 mg/ltr to 1260 mg/lt, destruction of VS was found to be 60.13% in this research. Similarly, the TS decrease from 6100 mg/ltr to 2500mg/ltr with utilization of 3600 mg/ltr. The cumulative volume of the biogas yield was 945-liter, maximum daily production of 47.50 liters was observed on the 9th Day of the experiment of corresponding pH 6.5 and temperature 21.8ºC. Also, the average daily biogas production was observed to be 17.18 liters.

Keywords
biogas, methane, horse dung, renewable energy, biomass

1. Introduction

Energy is the basic for life existence. Carbon as energy source and nitrogen for building the biological cell by living creature has inundated our planet Earth since the life origin. The human quest for harnessing the renewable energy has triumph with the invention of modern technology. Biogas is eco-friendly sustainable source of renewable energy which is economically and environmentally compatible to consume. Biogas generations through organic waste has varied usability like: thermal, electric etc. The digested biomass is a convenient source of organic fertilizer which is a key factor on multiplying the agro-productions maintaining the environmental sustainability [1]. Nepal has abundant ways for exploitation of adequate natural resources for energy purpose, Yet the fraction of its limit had been achieved due to many geographical, technical, economic and political reasons[2]. Nepal has only 260 kWh per capital energy consumption, significantly less than the world average of 3081 kWh per capita [3].

The global Environmental Performance Index report released in 2020 ranked Nepal as one of the worst for air quality among 180 countries[4]. The biogas support program (BSP) implemented in 1992 has successfully contributed to the publicizing the biogas technology in Nepal and helped in reduction in dependency on traditional fuels by introducing a sustainable alternative.

The positive impact on health and environment of using the biogas technology has benefited the thousands of households in Nepal, due to its higher cost for construction it has been lagging to touched the more portion of the population. Installation of biogas plant has been completed at all the local levels of 77 districts. Studies have shown that, along with

the biogas installation (as presented in Figure 1) the situation of health and sanitation is being gradually enhanced; deforestation (for the cause of firewood) is being curbed in Nepal[1].

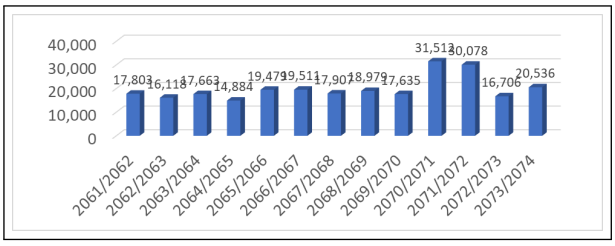

Figure 1: Biogas Plant installed in Nepal from FY 2061/62 to FY 2073/74.

Managing the solid waste is one of the major challenges in the urban zone as per change in land use where land value are precious. On the same context situation at the horse stable inside Naranyanhiti palace ignites challenge for waste management of above hundred horses due to the foul smell production and deficit of land for safe disposal. Hence, this study aims to finds the suitability of methane gas production from horse dung and aims for stabilization and reuse as manure through the large-scale biogas plant establishment funding from agencies working in biogas plant under renewable energy production.

2. Methodology and Experimental Procedures

This experimental study includes design of a pilot scale model in 200 liters digester, experimental setup, sample extraction and analysis on site and in lab of the collected samples. Analyze and test of parameters like: - pH, temperature, alkalinity, gas volume and percentage composition of methane and carbon dioxide in the produced biogas were measured on site, whereas parameters like: - Total Solids (TS), Volatile Solids (VS), NPK value were measured in lab. The model was setup in Kathmandu Valley at Nayabazzar area. The source of biomass substrate was extracted from Narayanhiti horse stable. The required inoculum was extracted from Nepal Academy of Science and Technology (NAST, Lalitpur), Moreover a small amount of cow dung was added for enhancing the preliminary phase of bacterial colonization. This research study was carried out from 30th April 2021 to 23rd June for 55 days period. Sample in-situ analysis of alkalinity were performed on weekly basis at the site itself while VS and TS test sample were extracted and deepfreeze and later all eight samples were tested on Institute of Engineering, Pulchowk Campus, Environmental lab on 28th Jun 2021.

Experimental Setup: 200-liter drum as digestor for batch reactor has been used for the research. Water displacement method is an accurate, simple and economic method used for determining of the volume of biogas produced. Two opening as substrate inlet and biogas outlet on the top portion of 200-liter drum were air tightened using 1.5" socket. One 0.5" hole at half feet above base is fitted with air tight tap for collection of biomass substrate during the research period for measuring TS, VS, alkalinity and pH. The digester has been kept inside the wooden cubical box arrangement laminated with P-form sheets on all walls for controlling of influence from external environment to the digester.

Also, thermostat has been adjusted so as to cutoff the minimum temperature limit. In-situ lab was set up for instant measurement of pH, temperature and alkalinity of the substrate sample on regular basis. COVID-19 pandemic has hit so hard that the necessary chemicals required throughout the process was purchased initially for lab setup on site; experiment and analysis requiring the university lab were stored under deep freezer. A portable biogas analyzer for CH_4, CO_2, H_2S and O_2" was used for determining the percentage composition of biogas. The schematic diagram of the experimental setup is shown in Figure 2.

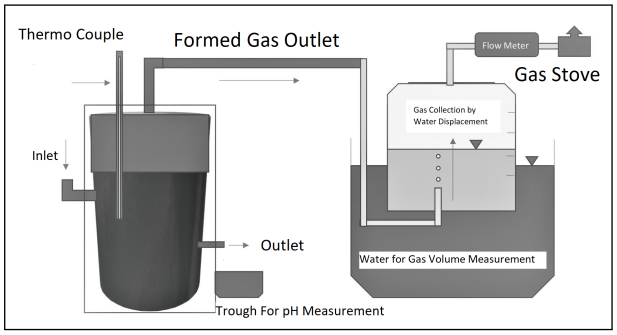

Figure 2: Schematic diagram of the Experimental Setup for Biogas production.

Preparation of sample: Fresh horse dung was collected removing the undesired materials. From the collected raw material sample were send for analysis of TS, VS, pH, N, P and K values. Well water for dilution to seven percentage of total solids. Inoculum provided from the National Academy of Science and Technology (NAST) were injected in the digester. Similarly, 1.39kg of cow dung were also added as

supplement such that the rumen of cow has methanogens inbuilt and helps to accelerate the biological activities for methane formation. After completing the pouring process into the digester, the drum was air tightened for batch reaction process.

Test and Measurement: Data from collection, preparation of the raw substrate to the disposal of digested substrate was noted and laboratory analysis and calculations was performed.

Characteristics of feeding Material: The characteristics of the feeding material used for the study are presented in the Table 2.

Table 1: Characteristics of feeding Material

SN	Parameter	Feeding Material
1	pH	07.20
2	Total Nitrogen	00.32%
3	Phosphorus	00.70 mg/gm
4	Potassium	04.84 mg/gm
5	Total Solids	28.00%
6	Volatile Solids	24.00%
7	Alkalinity	2220 mg/ltr

Sample analysis at field: Analysis of the substrate on the parameters like: pH, temperature, composition of gas and volume of biogas produced were determined on the daily basis whereas the alkalinity of the substrate were determined on the weekly basis.

Figure 3: Alkalinity measurement at site lab.

Figure 4: Sample extraction.

3. Results and Discussion

pH and Temperature: Thermostat installation at the insulation gap between digestion chamber and digester has nullified the ambient temperature effects inside the batch digester, also daily temperature recording was noted to verify the desire consequences to maintain within the stipulated temperature range. Developing insulation mechanism help raise the temperature inside the digester and enhance gas production at cold climate. The record of pH and temperature during the study period is shown in Figures 5 and Figures 6 respectively. Figure 5 shows the sets of temperature curves observed during the study period. Highest temperature was 22.6°C on the 47^{th} day of the study period and the lowest temperature was 20.0°C observed on the first day of the study period. The average temperature after analysis was found to be 22.06 °C. It has been found that the temperature gradually increases to a level and moved side-wise from 21.5°C to 22.5°C throughout the study period.

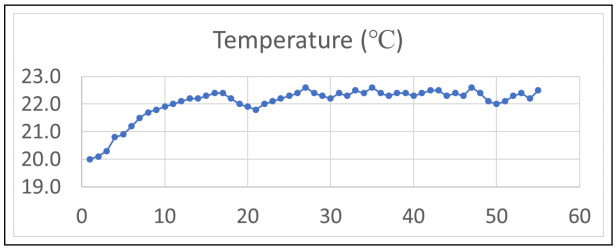

Figure 5: Temperature variation with time.

Figure 6 shows the sets of pH curves observed during

the study period. Highest pH of 7.3 on the first day of the study period was noted. The lowest pH of 5.8 was observed on the early twenty days (21, 22) of the study period. The average pH of the study was found to be 6.62 which lies in the favorable range of biogas yield. Bacteria are sensitive to pH ranges in anaerobic digestion where pH should be maintained between 6.6 to 7.6 during the digestion period.

Initially pH seems to decline indicating the hydrolysis and acidic phase where volume of gas produced was higher and later the curve reverts to near the previous layer indicating the acetogenic and methanogenic phases. 60% of the pH range in this study was found to be in the desired zone of 6.6 to 7.6.

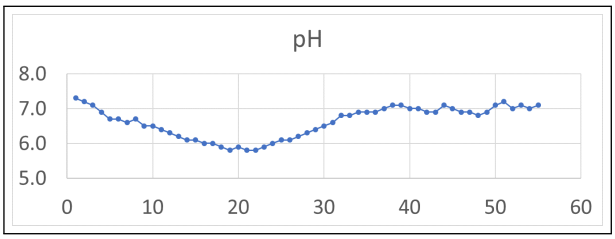

Figure 6: pH variation with time.

Volume of Biogas Produced: The volume of biogas generated is presented in the Figure 7. It can be seen that the peak biogas generation was 47.5 liters on the ninth day of the study where the corresponding pH of 6.5 and temperature 21.8°C. Figure suggests that the biogas generation subsides during the middle portion of digestion process and reoccurs after rise in corresponding pH value. Delay on gas production occurred due to lowering of pH values where sensitive bacteria were slow in biogas generation process. On average the biogas generated was recorded to be 17.18 liters per day. The cumulative biogas yield was 945 liters as shown in Figure 8.

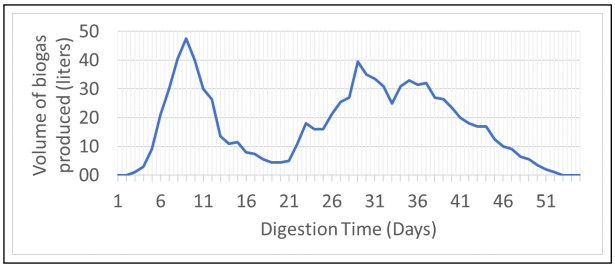

Figure 7: Volume of biogas generated.

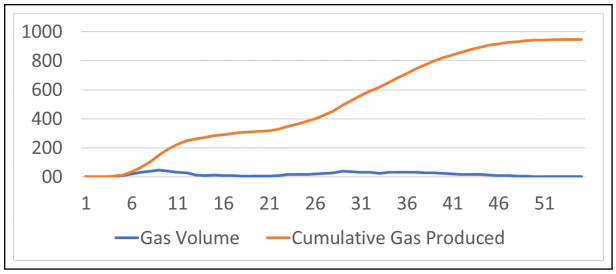

Figure 8: Time Vs Cumulative biogas yield.

Concentration of Methane in Biogas: The percentage composition of methane and carbon dioxide content in the biogas produced was measured by Biogas Analyzer (SA500 brand, Model IRCD4) provided for research purpose through Alternative Energy Promotion Center, New Baneshwor, GoN. % composition of CH_4 and CO_2 measured during the study period has been presented in Figure 9.

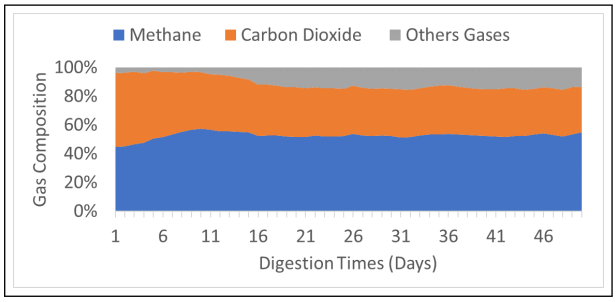

Figure 9: Percentage composition of CH_4, CO_2 and other gases on biogas yield.

Figure 9 shows that the percentage of methane in biogas was higher than of carbon dioxide. Graph shows the gradual increase in % composition of methane gas with respect to time till the 12th day (i.e.11th May 2021) and remains nearly unchanged till the end of the experiment. Similarly, the % composition of carbon dioxide gas reduces gradually till 27th day (i.e.26th May 2021) and remains steady on range of 31% to 33% composition. Likewise, % composition of other gases increases from zero to 15% till 27thday of the experiment and nearly remains steady below 15% composition throughout the digestion period. The gradual rise in % of methane and simultaneously decrease in carbon dioxide is attributed to proper digestion of biodegradable raw material. Maximum and minimum methane content was found to be 57.2% and 46.5% on the 12th day and 3rd day respective during the study period. Whereas, carbon dioxide % composition was found to be maximum of 51.23% on 3rd day (pH=7.1, T=20.3°C)

and 31.8% on 52nd day (pH=7.0, T=22.3°C) respectively.

Total Solids (TS) and Volatile Solids (VS): Biogas yield is directly proportional to the % destruction on the Volatile Solids (VS) present on the feedstock biomass. Here, VS decreased from 3160 mg/ltr to 1260mg/ltr with 60.13 destruction percentage. Similarly, Total solids (TS) reduced from 6100 mg/ltr to 2500mg/ltr. The total solids (TS) and Volatile solids (VS) destroyed during the anaerobic digestion process in this study has been presented in the Figure 10.

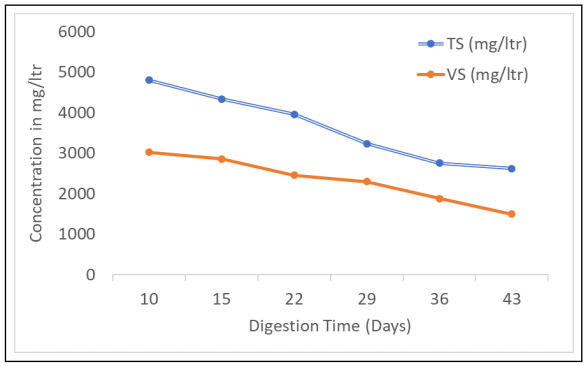

Figure 10: TS and VS destroyed during anaerobic digestion for methane production.

Alkalinity Analysis: Alkalinity is a chemical measurement of sample's ability to resist changes in pH on addition of acids or bases. It simply portrays sample's buffering capacity ability to neutralize acids. The alkalinity surge from 2220 mg of $CaCO_3$/ltr to 1090 and bounced back to 1800 indicating low resist as buffer solution for pH change.

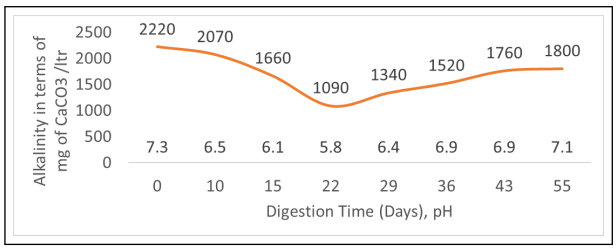

Figure 11: Alkalinity as per corresponding pH.

4. Conclusions

From this study, the investigation on the % composition of CH_4 and CO_2 gas formed, change in pH, alkalinity, utilization of volatile solids, NPK values and fluctuation in temperature over the hydraulic retention time (HRT) in the batch type reactor help find the trend of the designated parameters and biogas yield from Horse dung. The following points have been concluded.

- There exists the sensitivity of biogas generations from the Horse dung over pH values fluctuations. On average, the 60% of biogas yield was dominated within the pH range of 6.6 to 7.1. Also, pH below 6.1, the biogas yield seems to decline.
- The reduction of volatile solids for horse dung was found to be 60.13%. The drop in VS occurred from 3,160 mg/ltr to 3,020 mg/ltr on first week and 2,860mg/ltr, 2,460mg/ltr, 2,300mg/ltr, 1,880mg/ltr, 1,500mg/ltr and 1,260mg/ltr respectively on the consecutive weeks through the HRT in the batch type reactor.
- The maximum biogas yield for horse dung in this study was found to be 0.43 m3/kgVS.
- Peak biogas yield was observed on the 9th day where pH was 6.5 depicting the methane composition of 53.20% and CO_2 of 43.35% respectively. The day at which the peak of gas generated was a function of initial volatile solid concentrations.
- Alkalinity of the substrate decreases initially with pH fluctuation in acidogenic phase and returns with rise in pH value.

Acknowledgments

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