Proceedings of IOE Graduate Conference, 2015
pp. 143–149

Production Of Biogas From Slaughterhouse Waste In Lalitpur Sub-metropolitan City

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Abstract

Abstract: Energy is the driving force for the development in all countries of the world. Biochemical processes, like anaerobic digestion, can also produce clean energy in the form of biogas from the waste generated from different sources. Waste generated from Slaughter House (SH) can also be used as feed for anaerobic digestion. There are a number of SH in Lalitpur Sub metropolitan City (LSMC), which generates a huge amount of waste every day. But no means have been developed to treat the waste for energy recovery. Thus, this research intends to study the feasibility of biogas production from SH present in LSMC. The amount of biogas that can be produced from 23 SH present in LSMC is 103.2 m^3 per day. The result shows that the average organic waste generated from each slaughter house is obtained to be 117 kg per day. Laboratory analysis of the samples was done to determine the pH, Total Solid (TS), Volatile Solid (VS) and Carbon Nitrogen (C:N) ratio and the values were 7.2, 24.5%, 79.5% and 22.7 respectively. Anaerobic digestion process was conducted in a mini digester of 20 liter capacity. One of the reactors was filled with SHW slurry and other with Cow dung (CD) slurry for comparative evaluation of the technology. The study was conducted in a batch reactor, for a period of 43 days, with daily average temperature varying between 20^0C to 28^0C. The experimental investigation shows the biogas yield from SHW is higher in comparison to CD, which is a proven technology in Nepal. The specific biogas yield from SHW was 0.201 m^3/kg VS which is higher in comparison to CD, having 0.18 m^3/kg VS. The average methane content of SHW was 55.8%, which is in par with the methane content of CD.

Keywords

Salughterhouse waste, cow dung, biogas, methane

1. Introduction

Biogas is a flammable mixture of different gases that is produced by decomposition of biodegradable organic matters by microorganisms in absence of air (or oxygen). Biogas is produced by anaerobic digestion of biological wastes such as cattle dung, vegetable wastes, sheep and poultry droppings, municipal solid waste, industrial wastewater, landfill, etc. Main products of the anaerobic digestion are biogas and slurry. Biogas is constituted of different component gases the majority of them being methane, 50 -70 % and Carbon dioxide, 30 - 40 % with traces of Sulphur Dioxide and Hydrogen gas. The main objective of this research work is to investigate the potential for producing biogas from residues of slaughter houses within Lalitpur Sub metropolitan City.

Following are the specific objective of the research work.

- To identify the sources and characteristics of slaughterhouse waste for biogas production.
- To determine the total solid, volatile solid, organic carbon and nitrogen contents of the feedstock.
- To conduct the measurement of daily production of biogas in lab scale.
- To record the pH, temperature and analyze the methane content of the gas.
- To determine the fertilizing value (N,P,K) of the slurry.
- To analyze the economic viability of the biogas plant.

2. Methodology And Experimental Procedures

2.1 Field Survey

Sample from 6 slaughter houses were collected among 23 buffalo slaughter houses, from the major market areas in Lalitpur Sub metropolitan City which is 26% of the total slaughter houses.

2.2 Waste Characterization and Quantification

The waste generated from the individual animal executed was weighed; the weight of animal was noted before execution and after final preparation of meat for selling. The difference between the initial and final weight gave the weight of the total amount of waste (anaerobically digestible and non digestible waste). Later the anaerobically digestible and non digestible waste was segregated and it was weighed individually. Quantification of waste in a day was carried out by multiplying the average amount of waste produced from individual animal by total numbers of animals executed in a day.

2.3 Laboratory Analysis

The parameters that are required to analyze the biodegradability of Slaughter House Waste: pH, total solids (TS), volatile solids (VS), organic carbon content (C) and Nitrogen content (N) were determined and the NPK value of the digested slurry was also tested after complete digestion.

2.4 Determination of quantity of substrates

The mini-digester was fed with samples in different proportion diluting the substrates i.e. cow dung and slaughterhouse waste to 8% TS.

Table 1: Dilution ratio of cow dung (CD) and slaughterhouse waste (SHW)

Sample	Mass (kg)	Water (litres)	Innoculum (kg)	Total TS (kg)	Total mass of slurry (kg)
CD	6.67	8.33	1.00	1.20	16.00
SHW	4.9	10.1	1.00	1.20	16.00

2.5 Experimental Analysis

The study was based on the principle of batch feeding into the digester. This experiment was conducted in 20 litre capacity water jar used as a small digester (Figure 1). The contents in the digester were as per the substrate composition mentioned in Table 1.

Following sequential steps were taken for designing the digester. A hole was made on the top of the digester with a drill. The hole was about half inch in diameter. Gas flow pipe was fitted to the hole. A regulating valve was connected to the gas flow pipe, to control the flow of gas. Another hole was made at about 1/3 height of the digester at the lateral side, for slurry outlet. All the joining were completely made air tight by M- seal.

Inlet: The inlet was sealed by a cork. Since this is a batch type digester, there is no need to add substrates on a daily basis. The substrate is added once and the digester is sealed.

Gas line: A pipe attached on the top of the digester carried the gas from the digester. A regulating valve connected to the pipe line was used for controlling the flow from the digester. The gas was collected and measured by means of water displacement method.

Outlet: The outlet pipe was connected at about 1/3rd the height of digester. Its function was to take the slurry out of the digester to collect daily sample to measure pH.

Water seal: The pipe that carried the gas from the digester was connected to water seal, which is a trough of water. This pipe was fitted at the bottom of a graduated beaker, which was filled with water and kept upside down. The mini- digester was fed with samples i.e. slaughterhouse waste and cow dung, which were diluted to 8% TS. Laboratory study was then carried out in a batch type biodigester of capacity 20 L. Two reactors were used; one was filled with 15 kg of cow dung slurry and the other with 15 kg of slaughterhouse waste slurry. 1 kg of slurry from operating biogas plant was added to each digester as innoculum. The study was carried out for a period of 43 days. Daily measurement of temperature, pH and the volume of gas produced was carried out. The biogas was also tested for its chemical composition using gas analyzer. Since production of biogas from cow dung is a proven technology and well accepted in Nepal, one digester was operated fed on cow dung for

comparative evaluation of the technology.
Batch experiment setup:

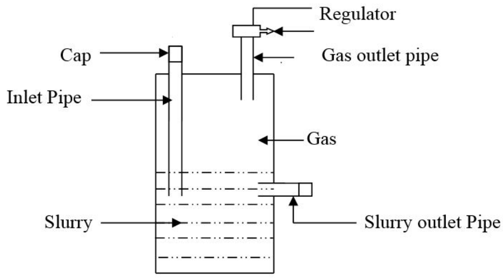

Figure 1: Schematic diagram of bio digester

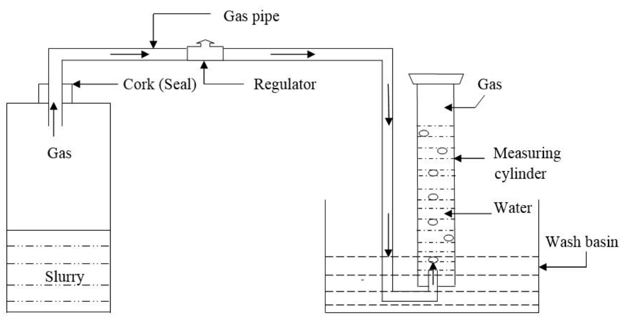

Figure 2: Schematic diagram of batch type biogas plant for laboratory study

2.6 Collection of feeding material

Slaughterhouse waste was collected from a slaughterhouse located at Iti in Lalitpur Sub metropolitan City for feeding the experimental bio- reactor. The innoculum was collected from operating biogas plant. Similarly, cow dung was collected from the local farmers nearby.

2.7 Data Collection

The volume of gas, temperature of reactor, pH of substrate and methane content of output biogas was recorded. These are considered the parameters of interest for our study.

3. Results and Discussions

3.1 Biogas potential from slaughterhouses

From the field visit, it was found that the slaughterhouses in Lalitpur Sub-metropolitan City are located in the areas shown in figure 3. Altogether there are 23 numbers of slaughterhouses at different locations and the total number of animal slaughtered in these areas varied from 2 to 20.

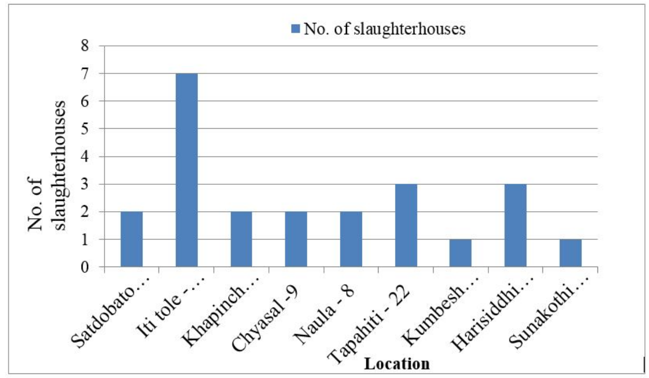

Figure 3: Number of slaughterhouses in Lalitpur Sub metropolitan City

After the field visits to the sites the average amount of the solid waste generated from each slaughter house was calculated as represented on Table 2. The amount of digestible waste generated was found to vary from 50 to 165 kg from six different Slaughterhouses. The average amount of waste generated from each slaughterhouse is 116.67 kg. This data is used to estimate the total amount of waste from 23 Slaughterhouses in in Lalitpur Sub metropolitan City.

3.2 Properties of substrates

The biochemical analysis of slaughterhouse waste and cow dung was carried out to determine the properties of these substrates.

Table 3: Biochemical analysis of cow dung and slaughterhouse waste

Parameters	Slaughter house Waste	Cow Dung
pH	7.25	7.1
Total Solid (TS) %	24.5	18
Volatile Solid (VS)%	79.5	75
Nitrogen (% dry mass)	2.03	2.2
Carbon (% dry mass)	46.2	43.6
C:N	22.75	19.81

Table 2: Quantification of the waste in Slaughter Houses in Lalitpur Sub-Metropolitan City

Name	Amount of meat in a Buffalo (kg/ buffalo)	Amount of total waste per buffalo (kg/ buffalo)	Amount of digestible waste per buffalo (kg/ buffalo)	No. of buffalo executed per day (buffalo/day)	Total Amount of digestible waste per buffalo per day (kg/ buffalo. day)
SHI	250	50	25	2	50
SHII	350	90	55	3	165
SHIII	200	80	60	2	120
SHIV	200	60	40	2	80
SHV	250	75	50	3	150
SHVI	300	65	45	3	135
Average	258.33	70	46	2.5	117

SH I – Satdobato, SH II – Ititole, SH III – Khapinchhe, SH IV – Naula, SH V – Tapahiti, SH VI - Kumbeshwor

3.3 Variation of influencing factors

3.3.1 pH

The pH value gives an approximate indication on the state of the fermentation process. Optimal pH value for anaerobic digestion process is in interval of 6.5 to 7.5 [1]. Some of the feeding materials have tendency of decreasing pH of the digestion slurry. In such a case the pH can be adjusted by the addition of calculated amount of lime (CaCO3). When nitrogenous materials are used for feeding, nitrogen is liberated in the form of ammonium hydroxide during the process of methane formation. This causes an increase in pH value of the media. If such condition appears, addition of straw would help ameliorate the pH [2].

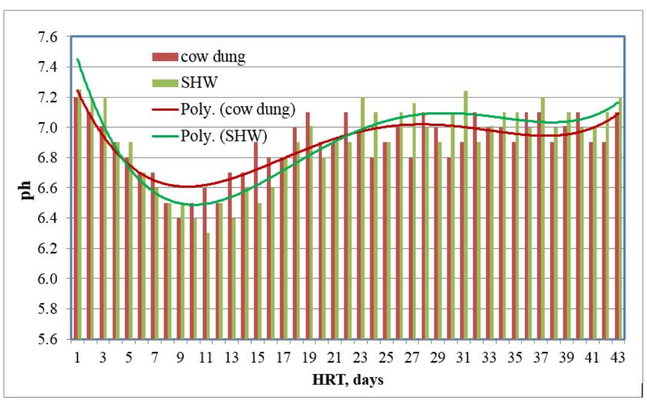

Figure 4: Change in pH of Cow Dung and SHW

During the experiment, the pH value of CD varied from 6.3 to 7.22 and that of SHW varied from 6.3 to 7.25. Initially, the pH decreased swiftly due to the increase in VFAs production by acidogenic bacteria as well as carbonic acid due to high concentration of carbon dioxide gas. The easily digestible fraction of organic matter was hydrolyzed and converted to fatty acids rapidly. The pH began to rise gradually as the Volatile Fatty Acids (VFA) was consumed by methanogens to produce methane. It was observed that there was stable pH after 4th week. The substrate was able to buffer itself and prevented the acidification occurrence during digestion due to proper alkalinity of the substrate. The result is consistent with the previous research [3].

3.3.2 Temperature

The temperature variation during the experiment has been shown in the figure 5. The temperature of the system lies within the mesophilic temperature range ie. 20 – 28 ^{0}C. Therefore, for optimum gas production, the temperature of digester can be increased by 7 - 10^{0}C, since optimum temperature at mesophilic condition is 35 – 37 ^{0}C.

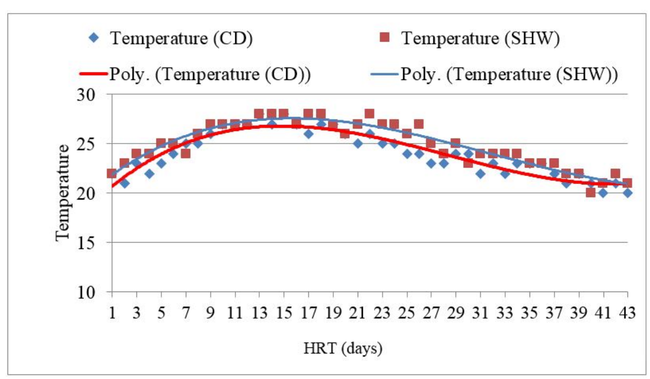

Figure 5: Daily average temperature profile of sample

3.3.3 Biogas generation

The daily biogas yield reached the peak value for CD in the second week whereas the SHW digestion reached its peak value on the third week. This could be due to the composition of paunch manure which is mainly fibrous material, rich in lignocelluloses. The decomposition of these fibrous matters takes longer time by microorganisms, since the content and distribution of lignin is responsible for the restricted enzymatic degradation of lignocelluloses, by limiting the accessibility of enzymes [4]. Biogas yield generally seems to be lower at the beginning and at the end of the digestion. This general trend is attributed to biogas production rate in batch condition which directly corresponds to specific growth rate of methanogenic bacteria in the biodigester [5].

The plot of the biogas cumulative yield is shown in figure 6. After 4 days of observation, biogas production started and continued until the end of 43 days detention period for CD and after 7 days for bio-digester containing SHW. [6] Wilkie, 2005 reported that cow dung has low volatile solids because ruminants extract much of the nutrients from the fodder. The low nutrient residue of CD as a result of enzymatic action of microorganisms in rumen of ruminant could be responsible for the least biogas production of CD. Hence, SHW has higher biogas yield than CD.

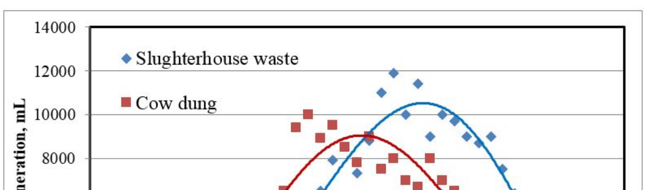

Figure 6: Biogas production from SHW and CD

3.3.4 Methane yield

The initial biogas production was due to the degradation of organic matter in the substrates and presence of methanogens from the innoculum. The low methane content was the result of the occurrence of hydrolysis stage and acid- forming stage, fermentative and acid forming bacteria were predominant in these periods. The biogas yield was then increased because of the growth of methanogenic bacteria, which utilized end products from the acid forming bacteria to produce methane. In this stage, methanogenic bacteria were predominant.

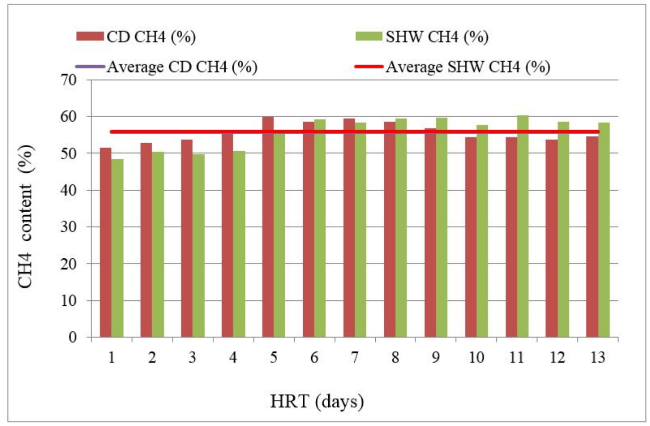

Figure 7: Biogas generated from SHW & CD

The daily biogas yield for the reactor containing CD reached a peak value of 10 L biogas with 59.80% methane content on the 12th day. Similarly, for SHW, peak value of biogas yield was 11.9 L with 59.76% methane content on the 18th day.

Methane content was measured after one week of gas formation for both the digesters. The percentage of methane content from SHW was found to be on par with cow dung.

3.4 Determination of Biogas Yield

The biogas yield from SHW was found to be 0.201 m^3/kg VS.

3.5 Slurry Test

The digested slurry from outlet was tested for NPK value at Agriculture Technology Centre, Pulchowk, Lalitpur. The results from the test are presented below:

Table 4: Chemical analysis of the slurry after digestion

Parameter	Digested slurry (CD)	Digested slurry (SHW)
pH	7.25	7.1
Nitrogen (N%)	0.63	0.90
Phosphorous (P2O5)%	0.76	0.50
Potassium (K2O)%	0.30	0.43

3.6 Potential of biogas energy from SHW in LSMC

The net feed is estimated to be 2690 kg/day (anaerobically digestible waste) which is the slaughter waste obtained from 23 SH present within LSMC. The total amount of gas production from the slaughterhouse waste of Lalitpur Sub metropolitan City is found to be 103.2 m^3/day, which is sufficient to provide 2 times meal per day for 464 people saving about 71 LPG cylinders per month. About 675 kg compost can be produced daily from the available waste.

3.7 Design Consideration of Bio Gas Plant

From the use of Bio gas Calculation tool version 3.1, the volume of biogas plant is calculated to be 753.2 m^3 for hydraulic retention time of 70 days. Since the volume of digester is very high and such high volume digester are not installed till today in Nepal and cost of transportation per day for carrying of feeder (slaughter house waste) to plant is assumed to be higher due to the locations of Slaughter house, so the concept of decentralizing of bio gas plant is made. For the decentralization, 753.2 m^3 of digester is broken down into 7 small bio gas plants with capacity of 100 m^3 of digester each. From each of those bio gas plants compost and bio gas shall be sold out.

For 100 m^3 digester: After decentralization, 13.8 m^3 of biogas can be produced per day from each biogas plant of 100m^3, which can provide 2 meals a day to 63 people in that area. It can replace 10.5 LPG cylinders per month and the amount of compost produced is 90 kg per day.

3.8 Financial Analysis

Table 5: Financial analysis of biogas for substitution of LPG

	With Subsidy	Without Subsidy
Net Present Value (NPV) NRs	629646.26	229646.26
Internal Rate of Return (IRR) %	16.23	12.6
Payback period (years)	5.3	6.7
Levelized cost of biogas	266.99 NR/kg	308.97 NR/kg
Levelized cost of electricity	56.17 NR/kWh	65.00 NR/kWh

The detail financial analysis was carried out in order to assess the feasibility of substitution of L.P.G by the biogas produced from slaughter house wastes. The financial evaluation was carried out for a single biogas plant with the digester size of 100 cubic meters. For rest plants, the result will be same. The calculation of payback period, NPV and IRR was carried out in Excel sheet. The result shows that the project is financially feasible with higher NPV and IRR.

4. Conclusions And Recommendations

4.1 Conclusions

The study concluded to the following:

- Slaughter House Waste can be used as a feeder for the production of biogas. The amount of biogas produced from SHW is higher in comparison to biogas production from cow dung, which is a proven technology in Nepal.
- The result shows that the average organic waste generated from each slaughter house is obtained to be 116.67 kg per day.
- The values of pH, Total Solids, Volatile Solids and C:N ratio obtained from laboratory analysis were 7.25, 24.5%, 79.5% and 22.7 respectively.
- The pH value, during the anaerobic digestion process lies in between 6.5 to 7.5, which is within favorable pH range for biogas generation.
- The specific gas generation from SHW was found to be 0.201 m^3/kg VS.
- The methane content of produced gas from SHW lies between 48.5 to 59.7% which is within the range of conventional biogas generation from cow dung.
- The amount of biogas produced from 23 slaughter houses present in Lalitpur is 103.2 m^3 per day.

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4.2 Recommendations

- Slaughter House Waste can be a good feeder for the production of Bio Gas, hence detailed study could be carried out on it.

- Before going for actual implementation phase, the study has to be carried out in larger digester, under continuous / semi continuous feeding system, to understand the operation in real practice.

- As this test has been carried out in limited time frame with limited resources, it is further recommended to carry out research using other advanced equipment like mass flow meter, volumetric gas flow meter compatible in low gas pressure.
- There should be mandatory requirement to establish biogas plants in each slaughterhouse (if land area is available) or at appropriate locations, both from energy development as well as environmental safety point of view.
- A fresh look towards the existing industrial generation aspect is to be explored creating suitable policy, subsidies and incentives. Research work on energy generation from slaughterhouse waste should be carried out. Special targets of the government should be on the large scale biogas plants as in developed countries. This is useful because a substantial amount of currency will be saved for the government in importing fossil fuels.
- Further study could be done on production of biogas from co digestion of slaughterhouse waste and wastewater.
- Prospects on fertilizer/composting techniques from the effluent of the biogas plant should be studied.
- Prospect of generating electricity from the wastes should be analyzed.

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