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Biochemical Treatment of Poultry Manure and Buffalo Dung to Enhance Methane Generation Using Lab-Scale An-Aerobic Digester: Effect of Mesophillic Condition on Methane Generation

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ABSTRACT

Poultry industry is one of the important growing poultry Industry of Pakistan, the pollution produced due to this causing serious environmental threats such as aquatic life disturbance, air, water and land pollution, pathogen contamination, bad odor, soil contamination and ammonia evaporation. This research study deals with utilization of poultry manure (PM) and buffalo dung (BD) for methane generation and enhance the generation through optimization of substrate mixing ratio and observe the effect of mesophillic condition on methane generation. The PM and BD were biochemically treated by anaerobic digestion. The mixing of P.M and B.D were carried out in ratio 3/1, 1/3 and 1/1 in 500 ml glass bottles acting as bio-reactor. The PM and BD alone were also used in different bioreactor. All the digesters have retention time of 65 days and operated at temperature of 37°C. Each digester distilled water and substrates were used in 1:1 ratio. All the digesters were operated by batch wise process. The generation of biogas from experimental work was maximum from 1:3 of P.M and B.D yield 561 Nml/gm.vs. The methane generation was also maximum in digester containing one part of P.M and three part of buffalo dung the methane generation was also maximum 66 %containing 32 % carbon dioxide. From this study we conclude that biochemical treatment of substrates mixed together in different ratios produces large quantity, quality, higher biodegradability and effective volatile solid removal from substrate.

Key words: Biogas, Digester; Poultry manure; Buffalo Dung and co-digestion

INTRODUCTION

The growth of world economy and progress of any country depend on energy. The population of world increase by 2.5 billion in the coming 40 years, increasing the population from 6.7 billion to 9.2 billion till 2050. Recently, the drastic depletion of fossil fuels and environmental deterioration have driven toward more sustainable energy (Umarin Jomnonkhaowa 2021). The burden on the fossil fuel in different commercial applications has caused serious environmental threats polluting land, air and water. Depletion of the sources of fossil fuels has divert the attention of world towards alternate energy resources (Seno and Nyoman 2010, Sharma, Agarwal et al. 2021). Renewable energy sources such as solar, wind and bioenergy are one of the important energy sources of different countries Fossil fuel consumption is major concern no a days due to the decrease in reservoirs (Rahman, Farrok et al. 2022) and increase of high prices (Esen and Yuksel 2013). The greenhouse gaseous emissions affecting the environment badly due to usage of various conventional sources of energy generation the replacement of conventional fuel by renewable energy sources is the best alternative to reduce these effects (Cuce, Harjunowibowo et al. 2016, Tutak and Brodny 2022).

Poultry Industry is one among one of the main industry of Pakistan. The population of the poultry increasing with 15 % per year has now reached to 73.65 million in Pakistan (Afzal 2006). The developing poultry industry has made people economy better around 1.5 million people groups are related with this field(Bolan, Szogi et al. 2010). The generation of PM and slurries from poultry farms put great burden in form of pollution on environment but now a days it is used for generation of methane and fertilizer purpose (Roshani, Shayegan et al. 2012)**.** According to economic survey of Pakistan report 2018-2019 there are 40 million buffalo's in Pakistan. The main product taken from buffalo dung are milk and meat. Although the dung generated from them given less attention. Recently some of small scale plants are installed in Pakistan but still research is in developing phase to use it for high scale application for methane generation since buffalo dung better potential to produce methane. This study will be helpful to see the production of methanogen bacteria's at mesophillic condition. It will be helpful in enhancing generation of methane.

The main theme of this study is to understand the importance of selection of high productivity co-digested substrate using various ratios. Following are objectives of this study.

1. To understand the effect of digestion of single substrate and digestion of two substrates together on biogas and methane production.
2. To find that which ratio of poultry and buffalo dung to enhance the generation of methane and biogas.
3. To determine effect of mesophillic condition on the production of methane.

The release of greenhouse gaseous is major concern during production of energy, anaerobic digestion is promising technology for treatment of organic waste generated from poultry and dairy industry (Kumaran, Hephzibah et al. 2016).There are various operating parameters that effect the production of methane such as moisture content, carbon nitrogen ratio and biodegradable content of organic waste (Matheri, Ndiweni et al. 2017). There are two ways used for treatment of poultry manure and buffalo dung by mono and co-digestion An-aerobic digestion resolve various technical issues.

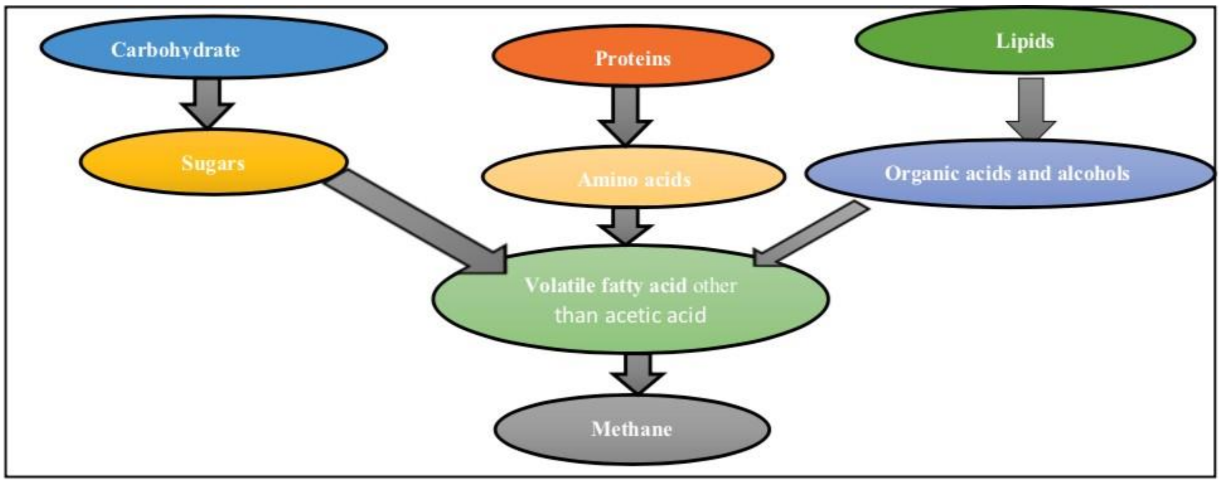

FIGURE 1. Steps of the anaerobic digestion process (Almomani and Bhosale 2020)

There is still not proper information regarding optimum mixing ratio of substrate poultry manure and buffalo dung. This study focused on the mixing strategy of poultry manure and buffalo dung for observing the performance, analyze, investigate and identify the optimum condition of temperature and alkalinity pretreatment using sodium hydroxide on anaerobic digestion process.

MATERIALS AND METHODS

SUBSTRATE COLLECTION AND PRESERVATION

The buffalo dung was collected from various buffalo yard located near Indus River Hyderabad and poultry manure was collected from various poultry broilers supplying vehicles from qasimabad Hyderabad. Each substrate was preserved in refrigerator at temperature at 4 ^{o}C to avoid degradation of substrate. The two different substrate was mixed in various ratios along with distilled water by commercial blender. The 50 g of each sample was collected for testing of volatile fatty acid, total solid, moisture, total alkalinity and pH.

PREPARATION OF SUBSTRATE

The substrate is first homogenized in a laboratory scale mixer in order to obtain a uniform composition of each substrate in the entire mixture. The reaction was carried out in a 500 ml glass bottle which served as a digester. The ratio of water to substrate is one by one. The 150 g of mixed substrate and 150 ml water. All the ratios can also be shown by Table 1.

ANALYSIS OF SUBSTRATE

The standard APHA method was used to describe the substrate and determine key variables such as moisture content, total solids content, volatile solid and total alkalinity [12]. A pH meter calibrated by Hanna was used to measure the pH. The results of various substrate analyzes are shown in Tables 2 and 3.

BIOGAS PRODUCTION MEASUREMENT

The measurement of gas will be carried out by gas chromatography. The measurement of gas will be carried out by water displacement method. These materials are very cheap, inexpensive and do not require long-term maintenance. They are made of simple materials like glass, plastic containers, and cylinders. The basic principle of the water displacement method is the used for measurement of gaseous (Young, Clesceri et al. 2005). The gas is collected using simple containers that contain the water that is displaced during the gas collection.

BIOGAS PRODUCTION ANALYSIS

The gas released during anaerobic digestion was measured by gas chromatography. A gas chrome meter was used to measure methane and carbon dioxide.

EXPERIMENTAL WORK

The experiment set includes a digester and a gas collector. The digester capacity was 500 ml and the gas collector 300 ml, both were glass bottles. The pipes between the digester and the gas collector consisted of plastic pipes with a diameter of 3 mm. A needle valve with a diameter of 3 mm was used to change the flow rate of the biogas produced. The volume filled into the digester was 3/4 of the total capacity of the digester. There were five digesters with a capacity of 500 ml. The digestion temperature was set with a 37 ° C water bath in order to control the biodegradation of organic waste. The daily room temperature was recorded with a thermocouple.

RESULTS AND DISCUSSIONS

In the present study, buffalo dung was mixed with poultry manure to produce methane and sludge. After 65 days of incubation of the samples, BMP remained for the substrates. Poultry manure (PM) and buffalo dung (BD) was digested alone. On the same time different mixing ratios of BD: PM was 1/ 3, 1/ 1/ 3 and 1/1 respectively. Operating conditions obtained were 37 °C in 500 ml digestions. The method for measuring biogas was water displacement. Methane analysis was performed using gas chromatography (GC) with a flame ionization detector.

CHARACTERIZATION OF SUBSTRATES

Total solids), Moisture content, Volatile solids, alkalinity and pH were determined using standard methods [12]. The results of the composition of substrate are shown in Tables 2 and 3. The results show that BD in substrate shows moisture content average value of 84.9%, while this value was 78.6 % for PM. Similarly, buffalo dung has a high level of VS % (volatile solid) from 84 % to 85 % and poultry manure has a lower volatile solid of about 60 percent. The pH of buffalo dung is between 7.2 and 7.5 and the pH of poultry manure is between 7.2 and 7.4. The total alkalinity of buffalo dung is 100 ± 3 mg $CaCO_3$ /L and poultry manure from 402 ± 1 mg $CaCO_3$ / L. Poultry manure contains high amounts of volatile fatty acids of 805 ± 5 mg / L and buffalo manure has a low proportion of 149-153 mg / L. For the bio methane potential, BMP can be specified in milliliters per gram of VS (Salminen and Rintala 2002).

TABLE 1. Characterization of poultry manure

Sample	Moisture Content %	Total solid %	Volatile solid % Out Of Total solid %	Total Alkalinity (mg/l)	Volatile Fatty Acid (mg/l)	P.H
S_1	79.6	23.2	60.4	401	810	7.4
S_2	78.0	21.3	60.03	402	800	7.2
S_3	76.6	23.4	61.67	403	805	7.3
Average	78.6	22.6	60.7	401.6	805	7.3

TABLE 2. Characterization of buffalo dung

Sample	Moisture Content %	Total Solid %	Volatile solid % out of total solid %	Total Alkalinity (mg/L)	Volatile Fatty Acid (mg/L)	P.H
S_1	85.3	16	83.3	103	149	7.2
S_2	85.5	15.6	84.78	106	153	7.4
S_3	84.1	15.9	84.35	100	149	7.5
Average	84.9	15.83	84.14	103	150.3	7.3

The digester A produces biogas from the third day due to its highly volatile fatty acids, since poultry manure is used as substrate in this digester. The bacteria are active here and have a lower storage phase. [9]. Biogas production from digester A peaked in between 8 to 14 days and began to decline. The cumulative biogas production was 440.3 Nml or 134.33 Nml / g.v.s the Abdul Razzaq Sahito stated that the production of biogas 149 Nml.gm^{-1}VS^{-1} is a crop residue (Sahito, Mahar et al. 2013). Digester B contains only buffalo manure. Production started on the fourth day due to the amount of volatile fatty acids in digester. The results showed that the digester B exhausted earlier than other digester. The observed total biogas quantity of the B digester was 242.8 Nml / gm.VS. Digester C contained mixed substrates of PM or BD in 1/3 due to the high proportion of poultry manure, and the early reaction started due to the balance of the C / N ratio, which balanced the biogas nutrients produced by Digester C 561.9 Nml / gm.VS. The generation of methance was greater because of balance of nutrient for methanogenic bacterias and suitable operating conditions. Digester D also contained a mixed substrate such as PM ad BD in a ratio of 3/1 due to the buffalo dung presence reaction started slowly on the fifth day with a high content of biogas, but the overall production was also low. The low proportion of volatile fatty acids in the total biogas production from Digester D reached 73.1 Nml / g.VS. Poultry manure and buffalo manure in a ratio of 1/1 were used in Digester E. Biogas production was high for the first few days and then behaved abnormally as it decreased from the sixth week to the last three weeks. The total biogas production from Digester E was observed to be 195.2 or Nml /gm.VS instead of. The following figure shows the amount of biogas production depending on the residence time.

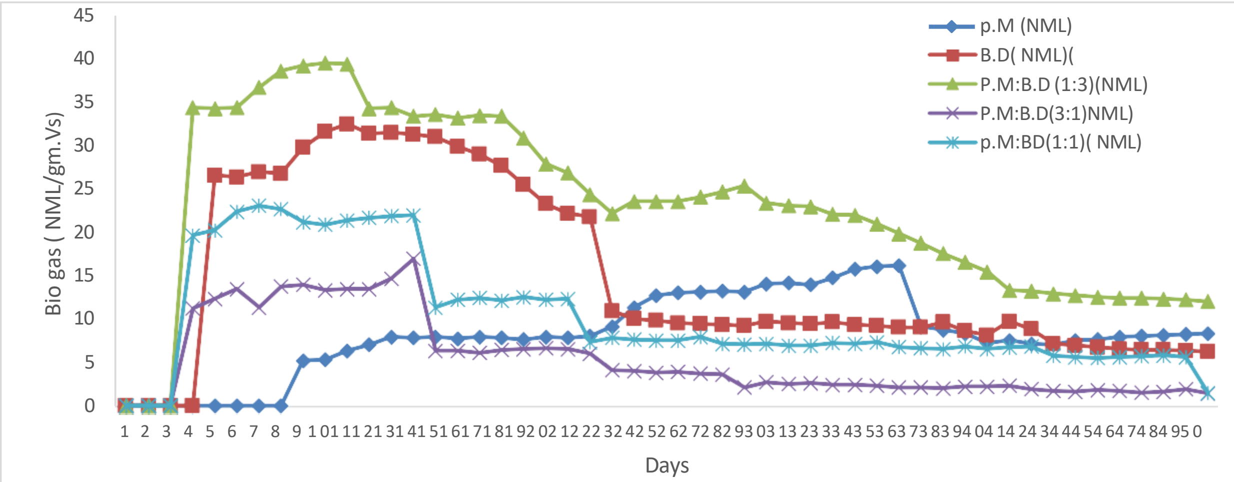

FIGURE 2. Biogas production v/s Days.

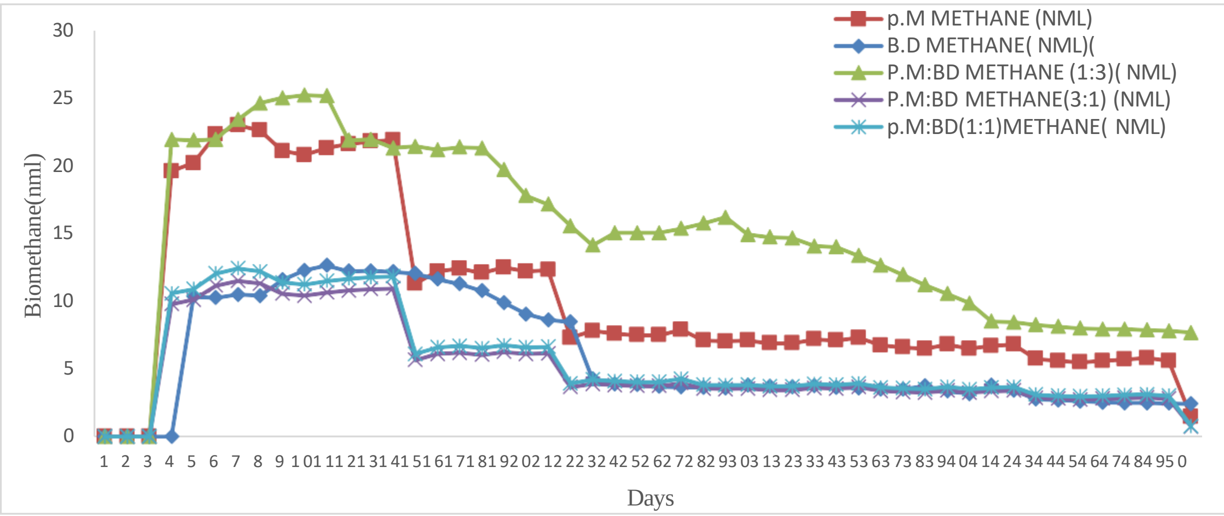

FIGURE 3. Bio methane production v/s Days.

ANALYSIS OF THE BIOGAS

The composition of the biogas produced was examined by gas chromatography. The quality of the biogas produced was increased by the passage of 2 molar NaOH solution. The quality of the biogas produced in poultry and buffalo dung was higher than 1:3.

TABLE 3. Composition of Methane from different digesters

Digester	Methane (Volume %)	Carbon dioxide (Volume%)
A	54	17
B	40	18
C	66	30
D	51	23
E	55	27

The following is a detailed analysis of the gas chromatography of various digester. The formation of raw biogas from digester A was observed by gas chromatography after treatment with 2 M NaOH. The results showed that the concentrations of methane and carbon dioxide were 54 vol % and 17% volume respectively. The remaining peaks indicate the concentration of other gases small percentage in the biogas sample.

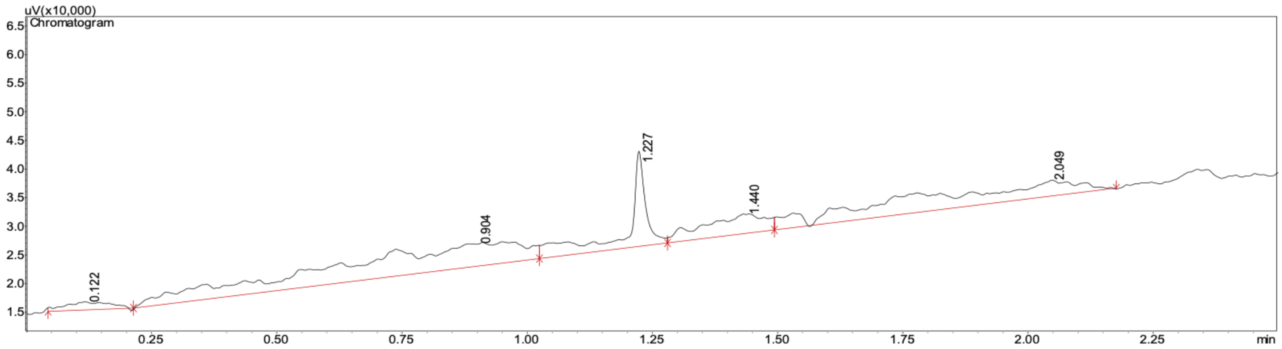

FIGURE 4. Chromatogram of methane from digester A

The formation of raw biogas from digester B was observed by gas chromatography after passing through 2 M NaOH solution. The results showed that the concentrations of methane and carbon dioxide were 40 % volume and 18% volume respectively. The remaining peaks indicate the concentration of other gases small percentage in the biogas sample.

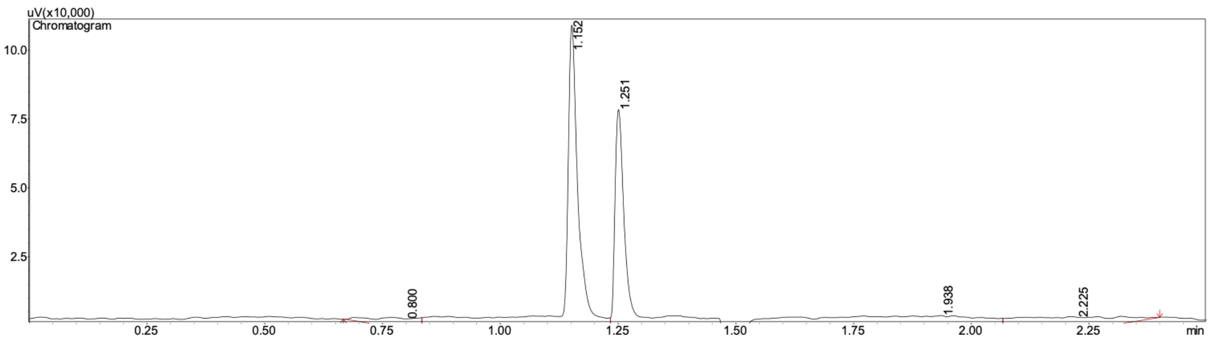

FIGURE 5. Chromatogram of methane from digester B

The characterization of raw biogas from digester C was observed by gas chromatography. The results showed that the concentrations of methane and carbon dioxide were 66 % volume and 30%, volume respectively. The remaining peaks indicate the concentration of other gases small percentage in the biogas sample.

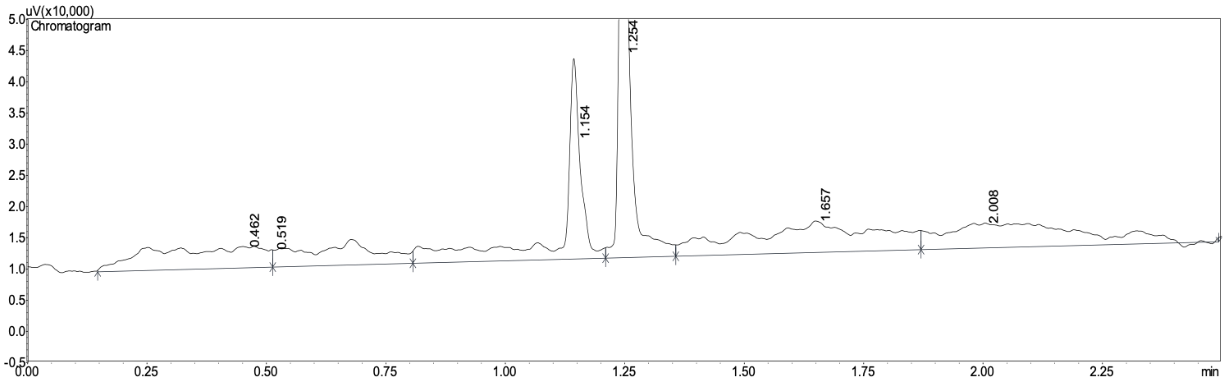

FIGURE 6. Chromatogram of methane from digester C

The formation of raw biogas from digester C was observed by gas chromatography after passing through 2 M NaOH solution. The results showed that the concentrations of methane and carbon dioxide were 51% volume and 23% volume, respectively. The remaining peaks indicate the concentration of other gases small percentage in the biogas sample.

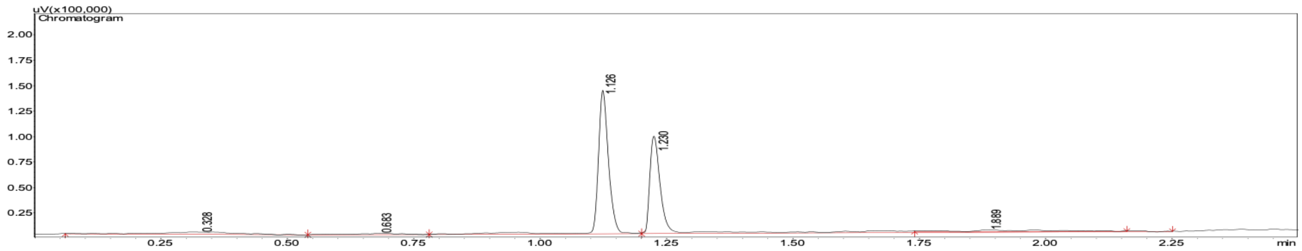

FIGURE 7. Chromatogram of methane from digester D

The methane formation from the digester E was observed by gas chromatography. The results showed that the concentrations of methane and carbon dioxide were 55% vol and 27% vol respectively. The remaining peaks indicate the concentration of other gases small percentage in the biogas sample.

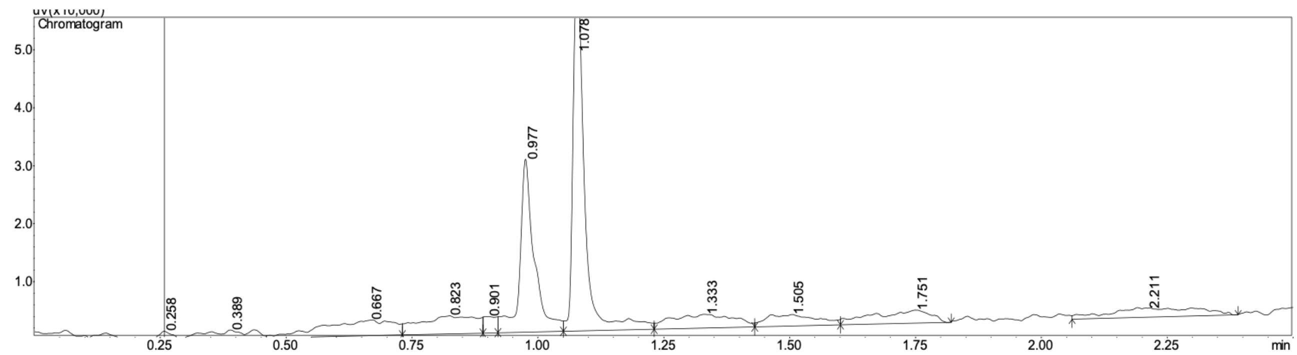

FIGURE 8. Chromatogram of methane from digester E

OVERALL PRODUCTION OF BIOGAS

Biogas produced by each fermenter was monitored using the water transfer method. The results showed that biogas from a single substrate of poultry manure or buffalo manure produced less biogas, while digester C with poultry manure and buffalo manure in 1: 3 produced the maximum amount of biogas 561.9 Nml /gm.vs by improving the carbon-nitrogen ratio of the substrate.

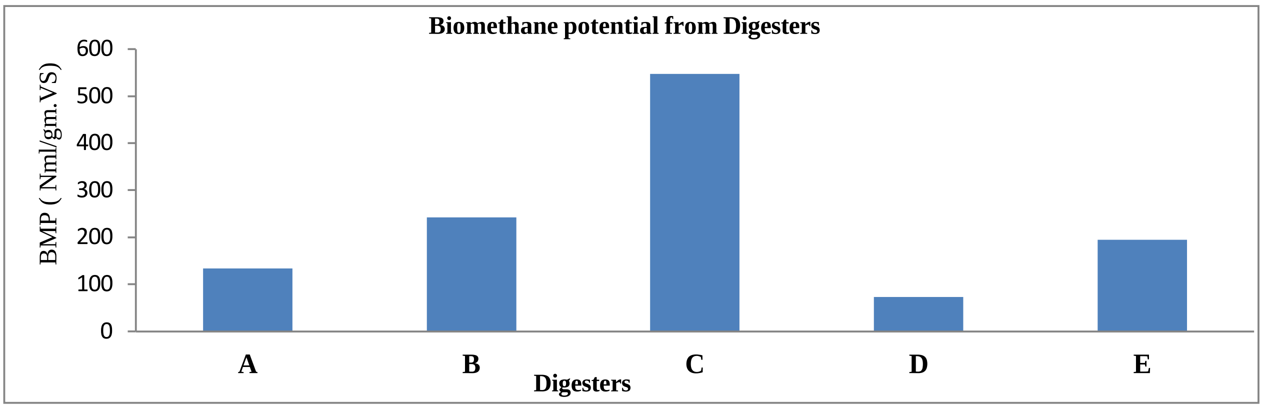

FIGURE 9. Bio methane potential from different digesters.

CONCLUSION AND FURURE RECOMMENDATION

The experimental work done in the laboratory was on poultry manure and buffalo dung It was used (1: 3) produces more biogas and methane. This experiment shows that the use of Buffalo Dung is individually producing less quality and quality biogas. Poultry manure began to produce biogas on the fifth day in the early days compared to Buffalo dung, so we mixed buffalo dung with poultry manure to increase biogas and methane production. This generation started the fifth day due to the presence of poultry manure in the digester such that results shows that poultry and buffalo dung mixed in 1/3 produces maximum amount of 561.9 Nml/ gm.vs biogas and methane concentration produced is also greater 66% in this digester because the C/N ratio was 20 to 30. More research is needed to determine the suitable inoculum to accelerate the anaerobic digestion reaction. It is also needed to work on thermophillic condition in order to select a better operating condition and use it at different conditions of temperature in different regions of world.

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DECLARATION OF COMPETING INTEREST

None.

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