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Research article

Potentiality of biomethane production from slaughtered rumen digesta for reduction of environmental pollution

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Abstract: Energy consumes by the world comes from fossil fuel which is non-renewable and pollute environment. Therefore, renewable energy is a possible solution for replacement of fossil fuel. Recycling rumen digesta can be considered as renewable energy source. Anaerobic digestion is one of the best processes for rumen digesta management which will lead to production of biogas, reduction in GHGs emissions and reduce environmental pollution. The purpose of this study was to assess number of slaughterhouse, amount of slaughtered animal, availability of rumen digesta in Sylhet City Corporation and generation of biogas from rumen digesta. The study was conducted in different locations of Sylhet City Corporation The experiment for biogas generation was carried out in 3300 ml digester under mesophilic condition. The mixing ratio of animal digesta and water was 1:1. Hydraulic retention time of the experiment was 40 days. The produced biogas was measured by water displacement method. The result showed that co-digestion of rumen digesta of chicken, cow, goat increased production of biogas. The maximum biogas generation from rumen digesta of chicken, cow, goat and co-digestion of three substrates were 27.2, 3, 39, 7.5 ml/day at the 12th, 28th, 9th, 1st day respectively. The average production of biogas from chicken, cow, goat and co-digestion of rumen digesta were 9.865, 1.32, 6.89, 6.35 ml/day respectively. The average methane production was 58.69%, 58.77%, 57.39% and 56.93% in biogas from chicken, cow, goat and mixed rumen digesta respectively. The study suggests making digester in every slaughterhouse for recycling rumen digesta and produce biogas which can recover future energy crisis and reduce environmental pollution.

Keywords: biogas; renewable energy; anaerobic digestion; slaughterhouse; rumen digesta

1. Introduction

Energy is considered as one of the key component for all development activities of human civilization. The source of energy is mainly classified into two categories i.e., renewable energy source and non-renewable energy source. Most of the energy used by world comes from non-renewable sources such as fossil fuel (coal, gas, uranium). But, the scarcity of this energy will be faced by world in the next few decades due to rapid growth of population and uncontrolled urbanization [1]. The sources of fossil fuel are being used in an alarming rate and these resources coming to an end. According to World Coal Association (WCA) and British Petroleum coal and natural gas will run out within 150 years and 52 years respectively. Due to the shortage of fuel, the cost of fossil fuel also increases with time. Also, uses of fossil fuel create some environmental problems. Moreover, greenhouse effect and global warming increase by releasing carbon dioxide when it burns. In this regard, worldwide energy crisis directed the attention to the renewable sources of energy replacement of fossil fuel. Renewable energy sources are an effective and efficient solution to mitigate this problem. Renewable energy source are those sources which are naturally replenished on human timescale such as biomass, wind, solar, hydro, wave. Among the sources rumen digesta as a biomass may be useful sources to produce renewable energy. Rumen digesta is animal waste which store into reticulo rumen, large chamber in where ingested feed is first subjected to microbial digestion. In 2010, the population of ruminant in world was about 3.6 billion, of which 5.38%, 39.59%, 25.19%, and 29.84% were for buffaloes, cattle, goats and sheep, respectively [2]. Although rumen digesta is valuable but it is treated as waste and frequently disposed into open environment and drain. These Disposal system of rumen waste may create environmental pollution, result in health hazard to human due to the presence of millions microorganisms. It also causes water pollution by entering into rivers, streams and other local sources. Moreover, it also responsible for greenhouse effect because of conversion into methane and carbon dioxide. According to Kyoto protocol exploited methane is 23 times more potential greenhouse gas than carbon dioxide [3,4]. Pathogenic organism is also found in slaughterhouse waste including *Clostridium perfringens, vibrio sp.,* [5]. Environmental pollution can be prevented by recycling of rumen digesta. One of the key method to recycle rumen digesta is to produce biogas as a renewable energy source. Due to the present of microorganism (cellulolytic and methanogenic bacteria) in rumen the bio-fertilizer and feeder can also be produced by recycling rumen digesta. The process of microbial fermentation in rumen and fermentation in digester to produce biogas are similar [6]. Biogas is a combustible gas produced by the anaerobic digestion (AD) or fermentation of organic matter. The organic matter can be manure, sewage sludge, municipal solid waste, biodegradable waste or any other biodegradable feedstock. Biogas is mainly methane, carbon dioxide and trace amount of H_2S, CO, NO. Among of the gaseous element, methane is the only combustible.

Anaerobic digestion is a series of biological process in which microorganism break down biodegradable material in the absence of oxygen. Digesters are kept at three different temperatures. They are ambient temperature (less than 25 ℃), mesophilic (25–35 ℃) or thermophilic (45–60 ℃) conditions. It is a step by step process where the organic carbon is mainly converted to carbon dioxide and methane [7]. The process of producing biogas divided into four step. A flow diagram of biogas production is shown in Figure 1.

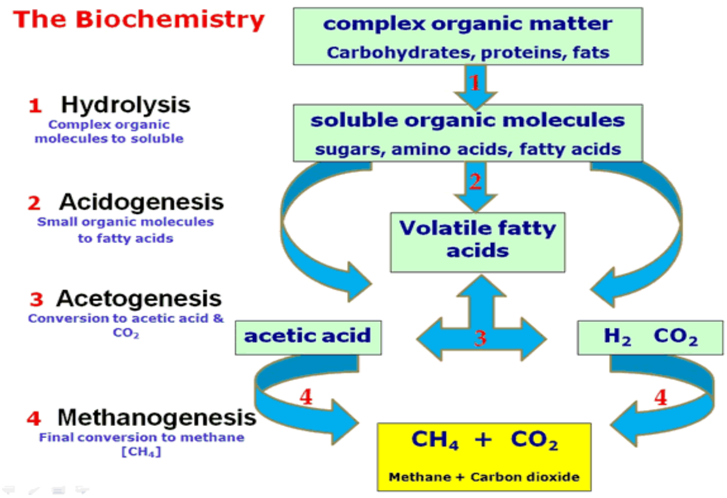

Figure 1. Flow chart of anaerobic digestion [8].

1.1. Hydrolysis

Polymer cannot directly utilize by fermentative micro-organism. In this step, bacteria break down the complex carbohydrates, protein, lipid into their monomer components (amino acids, sugar, and long chain fatty acid). Polymers are break down into soluble monomers through hydrolysis step as shown in Eq 1:

$$n(C_6H_{10}O_5) + nH_2O \rightarrow n(C_6H_{12}O_6) \quad (1)$$

1.2. Acidogenesis

In the second step, acidogenic bacteria decompose the amino acids and sugars into volatile fatty acids (VFAs) and alcohols. A simple substrate such as glucose can be fermented; different products are produced by the diverse bacterial community. Reaction: Eqs 2, 3 and 4 show the conversion process of glucose to acetate, ethanol and propionate (Angelidaki et al., 2007), respectively.

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2 \quad (2)$$

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2 \quad (3)$$

$$C_6H_{12}O_6 + 2H_2 \rightarrow 2CH_3CH_2COOH + 2H_2O \quad (4)$$

1.3. Acetogenesis

In this step acetogenic bacteria convert the VFAs into acetic acid, carbon dioxide, hydrogen. The conversion process is shown in equation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2C \quad (5)$$

1.4. Methanogenesis

In which the methanogenic bacteria convert acetic acids to methane and CO_2. According to the type of substrate utilized methanogenesis divided into two groups:

(1) Hydrogenotrophic methanogenesis: Hydrogen and carbon dioxide break down into methane according to the following reaction:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (6)$$

(2) Acetotrophic or aceticlastic methanogenesis: Methane is formed from the conversion of acetate through the following reaction:

$$CH_3COOH \rightarrow CH_4 + CO_2 \quad (7)$$

There are many studies available on biogas production from cow dung, solid waste. A study focused on waste reduction that comes from slaughterhouse and also investigated the possibility of biogas production from rumen digesta [9]. The ability of biogas production from slaughterhouse waste i.e., rumen fluid, rumen digsta, cow dung [10]. The initial phase of decomposition compare with methane formation phase can be reduced by using rumen fluid [11]. By using cow manure with rumen fluid and water for increasing production of biogas. This study showed the influence of manure, rumen and water in biogas production [12]. Pretreatment of waste paper with rumen fluid increase methane yield [13]. The effect of rumen fluid of animal ruminant to increase biogas production from cattle manure at mesophilic condition [14]. Therefore, there are few remarkable studies on biogas production from rumen digesta.

The present study focus on production of biogas as a renewable energy source by recycling rumen waste to control environmental pollution.

2. Materials and methods

Careful consideration is needed to select appropriate methods, procedures and design for collecting valid data. This chapter briefly describes the methods and techniques for assess the availability of rumen digesta and production of biogas. The study was based on field survey where the primary data were collected systematically by interview from people work in different slaughterhouse and recorded experimental data of biogas production from rumen digesta in the laboratory work.

2.1. Site selection

The primary data was collected from the different slaughterhouses of Sylhet City Corporation. Twenty slaughter house were selected for data collection from Shibgonj, Mirabazar, Bondar, Ambarkhana, Tilagor, ShahiEidghah.

2.2. Preparation of questionnaire

An interview schedule was prepared according to the objective of the project. All questions written in interview sheet were related to experiment. The interview was taken to know the amount of slaughterhouse, amount of slaughter animal per day/week/month, the amount of rumen digesta in cow/chicken/goat.

2.3. Interview schedule

Primary data were collected through personal interview with people who work in slaughterhouse. The reason of taking interview was clearly explained to respondents. During the interview time each question was explained clearly and tried to know the right answer from respondents. The collected data from the interview are shown in following Tables:

Table 1. Number of slaughterhouse established per year.

Year	Shibgonj	Ambarkhana	Kazitula	Shahi Eidgah	Tilagor	Bondr	Mirabazar
2013	17	2	6	1	2	16	10
2014	17	3	6	3	2	17	10
2015	17	3	7	3	2	19	10
2016	18	3	8	4	2	19	10
2017	18	3	8	4	3	19	11

Table 2. Number of slaughtered cow/goat/chicken.

Name of the place	Cow	Goat	Chicken
Shibgonj	18	25	130
Ambarkhana	3	5	180
Kazitula	7	10	200
Shahi Eidgah	4	8	250
Tilagor	3	6	200
Bondar	19	30	220
Mirabazar	10	20	180
Total	64	104	1360

Table 3. Quantity of rumen digesta from different slaughterhouse.

Name of the place	Cow (kg)	Goat (kg)	Chicken (kg)
Shibgonj	350	25	2
Ambarkhana	50	5	3
Kazitula	120	10	5
Shahi Eidgah	90	8	2.5
Tilagor	45	6	3
Bondar	340	35	5
Mirabazar	180	27	3

2.4. Collection of raw material

Cow rumen digesta was collected from slaughterhouse of Shibganj, Sylhet. Chicken rumen waste was collected from the slaughter house of Eidghah and baluchor bazar, Sylhet. Goat rumen waste was collected from slaughter house of Mirabazar, Sylhet. The collected raw materials were carried by air tight polythene bag. The collected raw materials were stored in the refrigerator at 0 ℃ to prevent the decomposition before the experiment. During the experiment the materials were kept in ambient temperature to regain its previous condition. The collected rumen digesta contains some undigested food such as grass, straw, grain.

2.5. Digestion sample preparation

Two sets of experiment were carried out in batch anaerobic digestion system. The first set of experiments were done to study the effect of rumen digesta for biogas production from single substrate and second set of experiment was done to study the effect of mixing ratios of cow, chicken and goat rumen digesta on biogas production via anaerobic co digestion. To complete the experimental set up rumen digesta of cow, chicken, goat was weighted. Then three individual sample were made from rumen digesta of cow, chicken, goat mixed with water in the ratio of 1:1. A co-digestion sample of rumen digesta was prepared in the ratios of cow: chicken: goat (1:1:1) and were diluted with water at 1:1 ratio. Due to presence of organic matter, protein and nitrogen in blood were taken from slaughterhouse. The all ratios of materials were mixed out properly by stirring to add the contact of each waste for obtaining homogenous condition. pH of sample was measured which was 6.6, 6.8, 6.6 for cow, chicken and goat respectively, 6.9 for co-digestion substrate with rumen fluid. The size of each digester was 3300 ml. 80% of digester was filled with prepared material. After adding the feedstock, the anaerobic digester was a tightly closed with rubber stopper. The quantity of rumen digesta used in reactors are shown in Table 4:

Table 4. Quantity of rumen digesta used in reactor.

Feedstock	Rumen waste (kg)	Water (kg)	Total weight of material (kg)
Chicken	1.36	1.36	2.72
Cow	1.36	1.36	2.72
Goat	1.36	1.36	2.72
Mixture	0.454 × 3	1.36	2.72

2.6. Experimental set up

The lab scale experimental set up was installed by using four 3300 ml digester, 1500 ml water-cum-gas chamber and 1500 ml water collector for every observation. The digester was connected with water-cum-gas chamber through 12 mm diameter hose pipe. Pipe was used to permit produced gas to flow from digester to water-cum-gas chamber. Gas created pressure on the surface of water and displaced same volume of water to flow in the water collector through 10 mm diameter hose pipe. One end of the gas pipe was connected to the top of digester with a glass tubing and other end was connected to the top of the water-cum-gas chamber. On the other hand, one end of water collector pipe was connected to the top of the water-cum-gas chamber and other end of pipe was connected to the water collector. Two gas flow control valve were attached with hose pipe. One was to control the flow of produced gas and other was to control the flow of water. Other instruments were used in that experiment include thermometer, pH meter, glass tubing, gas flow control valve, graduated plastic bucket. Biogas production was monitored for 40 days of study period and data was recorded. The temperature range was 25 ℃ to 30 ℃ during the study period. The schematic diagram of experimental set up is shown in Figure 2:

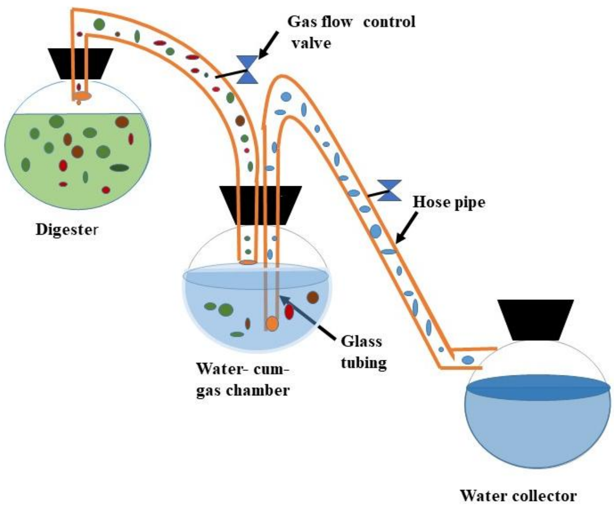

Figure 2. Schematic diagram of experimental set up.

2.7. Data collection of produced biogas

In this experiment the amount of produced gas was assessed by water displacement method. Data was collected every day at 2 pm in the Agricultural and Biosystem Engineering Lab, Department of Farm Power and Machinery, Sylhet Agricultural University.

2.8. Observation

Four observations were started after filling the digester with cow, chicken, goat, and mixed rumen digesta. The digesters were left for anaerobic digestion and gas was started to produce from first operating day and it was almost finished at 39/40th digestion day. Produced gas was measured directly through the measurement of the same volume of expelled water. Observation was continued till the flow of expelled water was stopped.

2.9. Analytical method

Samples were taken and prepared to measure pH of the sample by pH tester (HI98107, HANNA Instruments, Inc. Romania). Thermometer (TP300, China) was used to obtain daily temperature of study period as well as the daily ambient temperature of the environment. Temperature range of TP300 thermometer is −50 ℃ – +300 ℃. Gas composition was analyzed off line by gas chromatography (GC- 8AIT/C159 R8A SHIMADZU Corporation, JAPAN) and Testo-350 portable gas analyzer (Testo AG., Germany). The gas chromatograph was fitted with a

Porapak N 80/100, 274.32 cm, 1/8 mesh 250 × 250 × 145 mm column, a molecular sieve (Mole sieve 5 A 60/80, 182.88 cm, 1/8), maximum temperature 399 ℃, temperature stability ±0.1 ℃ a stainless-steel column and a thermal conductivity detector. Detector type was TCD made by Tungsten rhenium filament. Maximum temperature and sensitivity of the detector was 400 ℃ and 7000 (mVml/mg) respectively. Argon (Ar) was used as the carrier gas at a flow rate of 30 ml/min. The column temperature was 60 ℃ and the injector/detector temperatures was 80 ℃ and current 60 (mA). A 5 ml gas tight syringe was used to take raw biogas samples after releasing the gas. Microsoft Excel 2016 software was used to make the graphical analysis.

3. Result and discussion

3.1. Present scenario of slaughterhouse

Number of slaughterhouse in Sylhet City Corporation is shown in Figure 3. The bar graph shows that the number of slaughterhouse was increased 2013–2017 in all selected places. It is clearly seen that the maximum number of slaughterhouse was situated in Bondar and lowest number of slaughterhouse in Tilagor. The number of slaughterhouse was almost constant in the years of 2013–2015 might be due to public demand variation in different locations.

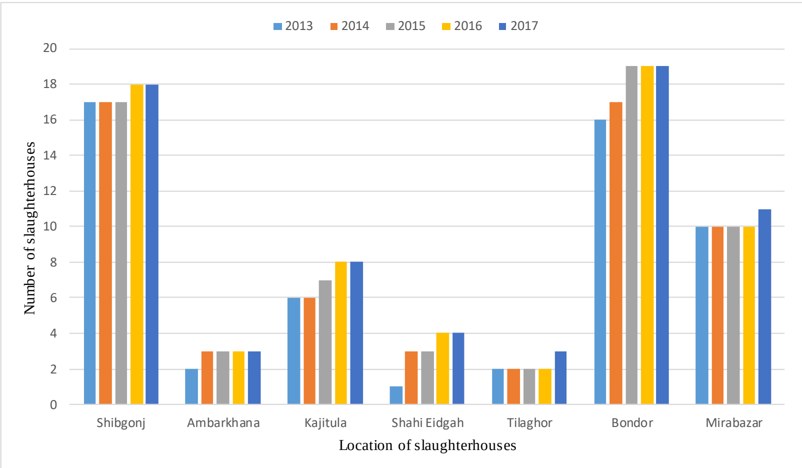

Figure 3. Number of slaughterhouse in different years.

Figure 4 illustrates that number of slaughtered cow,chicken,goat in different locations. The number of slaughtered chicken was high in every slaughterhouse compare to cow and goat. The result indicates that the slaughtered chicken's number was high due to the low cost and readily available. The result also shows that the slaughtered chicken's number was high in Shahi Eidgah slaughterhouse due to the central point of this area.

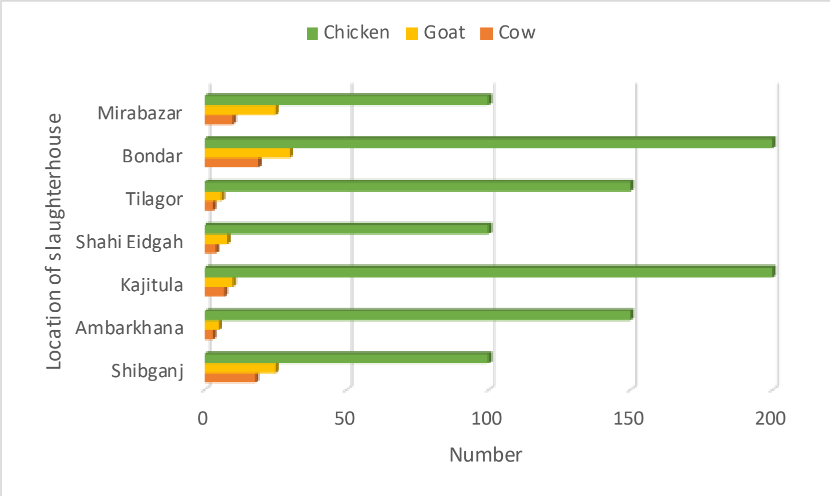

Figure 4. Number of slaughtered animal per day.

Amount of produced rumen digesta is shown in Figure 5. Amount of rumen digesta was high in shibgonj followed by Bondar in case of cow due to transition point from the all access road in Sylhet City Corporation. The Figure shows that the lowest amount of rumen digesta produced in Tilogor. It is clearly shows that chicken rumen digesta was produced in lowest amount among three sources due to size of the rumen.

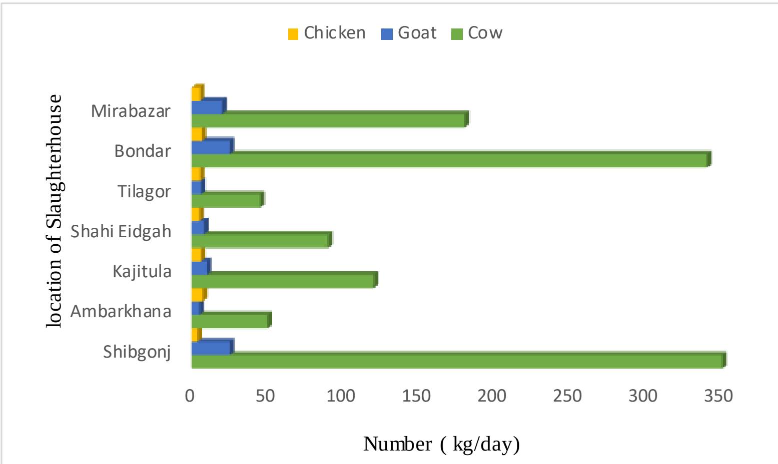

Figure 5. Quantity of rumen digesta.

3.2. Biogas production profile

The biogas production rate under mesophilic condition in batch type digestion system are shown in Figures 6 to 9. It was observed that gas production started from the first digestion day. Figure 6 represents the production of gas from rumen digesta of chicken. It shows that the study period was 40 days and the production starts from the first operating day due to the rapid decomposition of undigested food that means rumen digesta of chicken. Production was gradually increased until 5th day. Then production was decreased due to temperature fall. Maximum gas production was 27.2 ml/day which was recorded in 12th day of study period. The average rate of gas production was 9.865 ml/day.

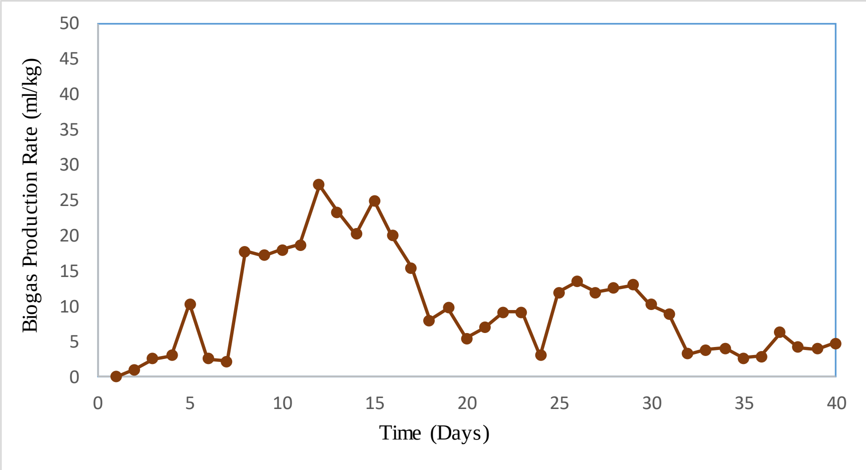

Figure 6. Biogas production from chicken rumen digesta.

The production rate of biogas from cow rumen digesta is shown in Figure 7. Under 40 hydraulic retention time the highest gas production was 3 ml/day at 28th day with high fluctuations due to pH and temperature variation. The average gas production was 1.3125 ml/day. This study shows that the production of biogas from cow's rumen digesta was less than chicken's rumen digesta. Although production starts from the beginning day but production rate was not so high. Because of the high amount of nitrogen in rumen blood. Moreover, microorganism which decompose undigested food need 30 parts of carbon for every part of nitrogen. Rumen digesta of cow which also contain some undigested food such as grass, straw which decomposed slowly which was indicated the upward trend of the graph after 40 days' hydraulic retention time.

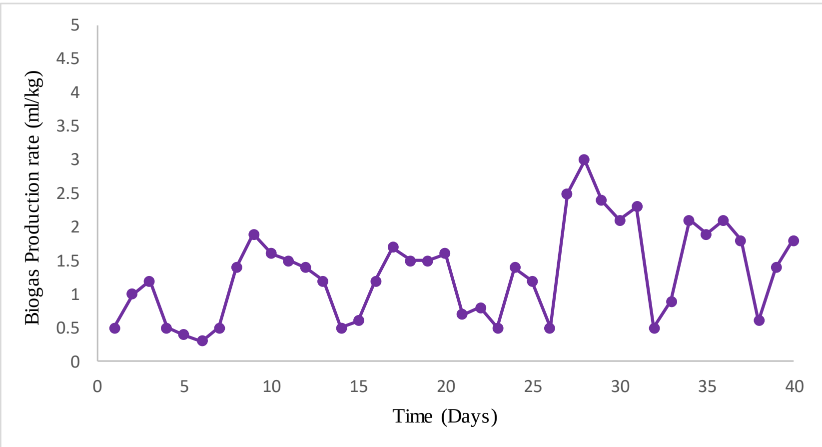

Figure 7. Biogas production from cow rumen digesta.

Figure 8 represents that the production rate of biogas from goat's rumen digesta. The maximum production of biogas was 39 ml/day at 9th day. After 15th day of digestion period production was decreased. The average rate of production was 6.89 ml/day. The undigested waste of goat needed less time to decompose as a result, at the beginning of retention period the biogas production rate was high. It also noticeable that the goat rumen digesta was diluted due to much water content during collection time. The investigation was observed that the biogas production rate was almost stabled from the 16th day to 40th day.

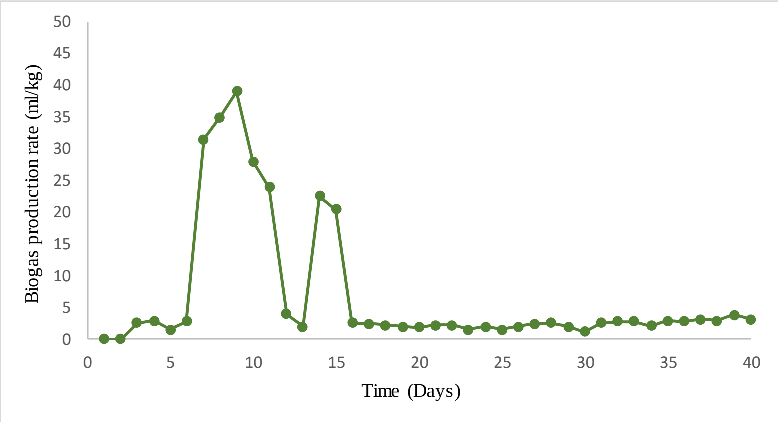

Figure 8. Biogas production from goat rumen digesta.

Production of biogas from mixed rumen digesta of cow, chicken, goat is shown in Figure 9. Mixed sample also contain rumen blood which consists of protein, total organic carbon 31.9%, organic matter 54.8%, nitrogen 12.3%, ammonia 8360 ml results ratio of C/N 2:7. Optimum carbon and nitrogen ratio is one of the key parameter for increasing biogas production rate. Therefore, use of blood increased the production rate at first two days. When all substrate of blood stabled production rate started to decrease. Maximum production was 7.5 ml/day obtained at the 1st day. The average rate of biogas production was 6.35 ml/day. The general prediction is that production rate directly related with the growth of methanogenic bacteria, temperature and pH. The study result reveals that biogas production rate was highly fluctuated over the digestion period.

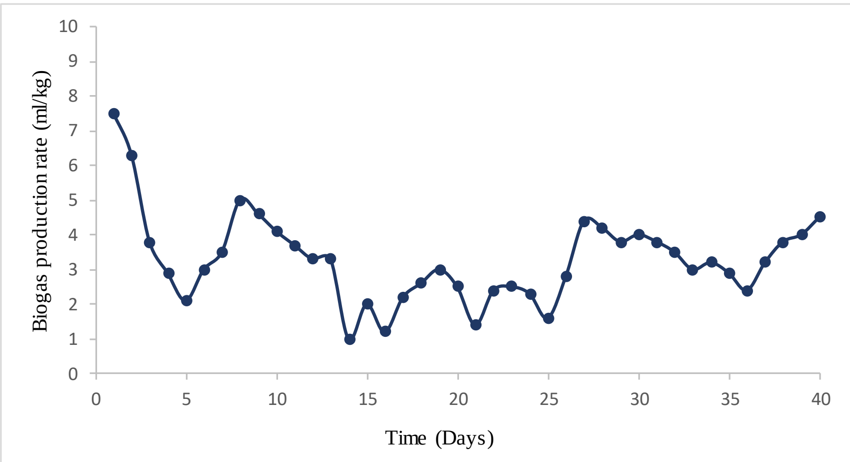

Figure 9. Biogas production from mixed rumen digesta.

3.3. Comparison profile of biogas generation

Figure 10 represents the difference in biogas production after every 10 days. The Figure reveals that after 10 days production was high in every digester except in digester which was filled with cow rumen digesta. The Figure also shows that biogas production from chicken rumen digesta was increased in 2nd 10 days then decreased in 3rd and 4th 10 days because of the highly decomposed rate was occurred after 10 days. Production of gas from cow rumen digesta was increased after every 10 days because of complete decomposition. The Figure shows that Production of gas from goat's rumen digesta was decreased in 2nd and 3rd 10 days and again increased in 4th 10 days means fluctuated over the retention time. The mixed digesta was produced high rate of gas in 1st 10 days because of co digestion of three substrate ratio due to positive synergisms established in the digestion medium and the supply of missing nutrient by the co-substrates. When blood content became stable production rate decreased in 2nd 10 days. Then gradually increased in 3rd and 4th 10 days. Figure also shows that highest gas produced from chicken, cow, goat and mixed rumen digesta was 101.6, 15.4, 143.3, 173.3 ml/day in 3rd, 4th, 1st and 1st 10 days respectively.

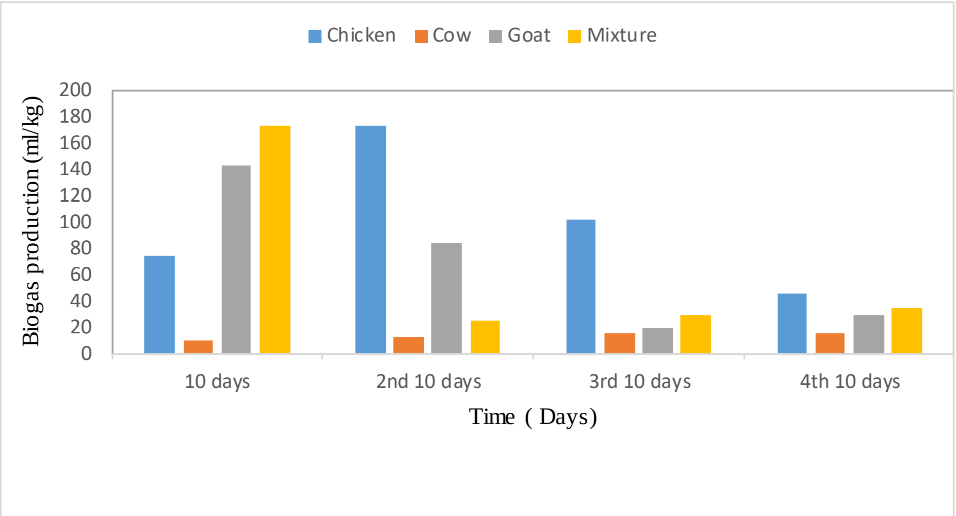

Figure 10. Variation of gas production after every 10 days.

3.4. Cumulative biogas production rate

Figure 11 represents the cumulative biogas production from rumen digesta of cow, chicken, goat and mixed digesta. The Figure shows that cumulative production of 52.5 ml (cow digesta), 394.6 ml (Chicken digesta), 275.6 ml (Goat digesta) and 258.4 ml (mixed digesta) was observed. The result shows that cumulatively highest production obtained at the last 10 days of study period. The average cumulative production of biogas from chicken, cow, goat and mixed digesta were respectively 221.57, 23.53, 186.02, 197.81 ml.

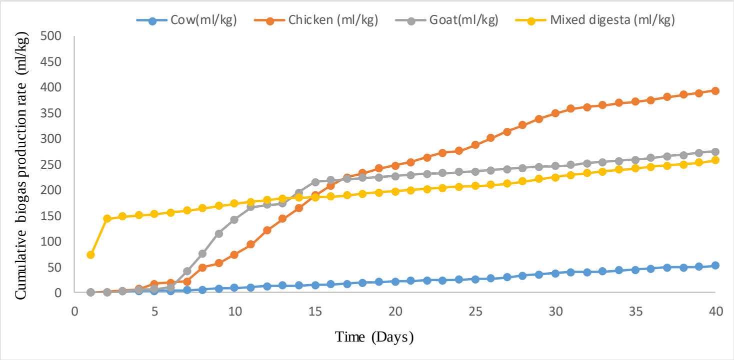

Figure 11. Cumulative biogas production rate.

3.5. Temperature profile

The daily temperature was noted during anaerobic digestion process. The temperature was in mesophilic range during study period. The lowest temperature was 23.8 ℃ which was obtained on 8th operating day. The highest temperature was 30.2 which was obtained on 20th operating day. The average temperature was recorded 26.8 at the end of 40 day's digestion time.

3.6. Methane content of rumen digesta

Figure 12 represent the percentage of methane present in produced biogas from rumen digesta of chicken, cow, goat and mixed waste. Methane production varied from 55–65%. The Figure also reveals that highest methane produced from chicken, cow, goat and mixed rumen digesta were 65.29%, 62.2%, 63.28%, 62.5% respectively. The Figure also shows that the average methane produced from chicken, cow, goad and mixed rumen digesta were 58.69%, 58.77%, 57.39% and 56.93% respectively. Average methane production was high in cow rumen digesta. Generally, the feedstock chemical characteristics such as the chemical composition (lignin, cellulose, hemicelluloses, starch, total soluble sugars, proteins, and lipids) can determine the gas generation by anaerobic digestion process. Methane yield vary for different chemical constituents of the same feedstock. Fats and proteins produce more methane than carbohydrates and lignin is not biodegradable under anaerobic digestion.

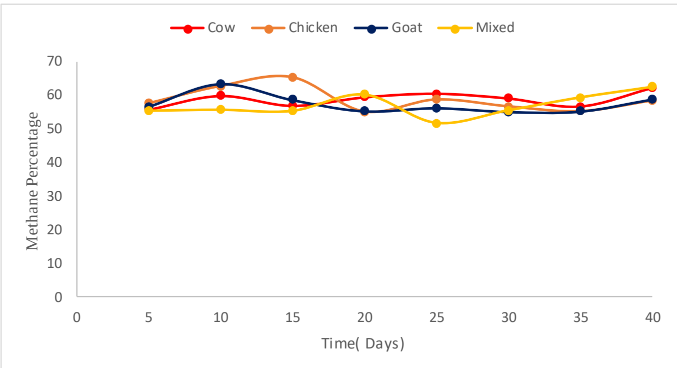

Figure 12. Methane content of produced biogas.

4. Conclusion

Energy plays a vital role in the world. Nothing can be done without the movement or conversion of energy. With the increasing population all over the world, the use of energy also increases. The increasing rate of using energy implies scarcity of energy. In this regard renewable energy is an effective solution. This study was focused on assessment of slaughterhouse number, slaughtered animal number, rumen digesta availability and the production of biogas as a renewable energy source by recycling rumen digesta. The highest production rate of biogas from chicken, cow, goat and mixed rumen digesta were 27.2, 3, 39, 7.5 ml/day respectively. The average production of biogas from rumen digesta of chicken, cow, goat and mixed digesta were 9.865, 1.32, 6.89, 6.35 ml/day respectively. The maximum methane production in biogas from chicken, cow, goat and mixed rumen digesta were 65.29%, 62.2%, 63.28%, 62.5% respectively. The average methane production was 58.69%, 58.77%, 57.39% and 56.93% in produced biogas from chicken, cow, goat and mixed rumen digesta. The results obtained from this study could be used as a basis for designing large scale anaerobic digesters for treatment of rumen digesta. Successful digestion of these substrates is a means of providing renewable energy and environmental friendly waste management system.

Acknowledgement

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Conflict of interests

The authors declare no conflict of interest in this paper.

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