Comparison Effect on Biogas Production from Vegetable and Fruit Waste with Rumen Digesta Through Co-Digestion Process

Anika Tasnim, Muhammad Rashed Al Mamun, Md. Anwar Hossen, Md Towfiqur Rahman and Md. Janibul Alam Soeb

ABSTRACT

Biogas is the best renewable energy as it can be produced from any biomass for example any plant or living organism. The purpose of this research was to produce biomethane from co-digestion of vegetable and fruit waste with rumen digesta through anaerobic digestion process. In this research, two trials of experiment were conducted. Each trial has three different sample with different mixing ratios. Raw materials used in the experiment was rumen digesta of goat and cow, potato, capsicum, cucumbers, onions, radish, cauliflower, carrot, leafy vegetables, apple, banana, and papaya. In each sample, 1200 gram of raw materials were used. Hydraulic retention time was 30 days. Data was collected by water displacement method. The experiment found that the gas production started from 2nd or 3rd days and stops in 28th or 29th day. Highest production of biogas was 35, 33, 30, 40, 50 and 35 mL/day on the 17th, 14th, 17th, 11th, 12th and 7th day at the mixing ratios of 1:1:2, 1:2:1, 1:1.5:1.5, 1:0.5:0.5, 1:2:2 and 1.5:1.5:1 (Rumen Digesta: Vegetable Waste: Fruit Waste) respectively. The study suggests making digester for the recycling of waste to produce biogas, a renewable and environment friendly energy.

Keywords: Anaerobic co-digestion, biogas, rumen digesta, vegetable and fruit waste.

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I. INTRODUCTION

Energy is an indispensable factor for development of human. People, all over the world, cannot even think to do regular house works for example cooking, storage of food, lighting home without the supply of sufficient energy. Currently, fossil fuels are the cardinal source of energy which can supply around 80% of the world's needed energy. Fossil fuel is fuel, formed by natural method such as anaerobic decomposition of buried dead organism. These micro-organisms have a limited age of millions of years and sometimes more than 650 million years [1]. Because of the shortage of fossil fuel, the cost will also increase with time. In addition, the burning of fossil fuels generates carbon dioxide (21.3 billion tons) every year. Carbon dioxide is known as greenhouse gas that expands radiative forcing and contribute to climate change. However, within 1000 years, it will not be possible to reverse the condition of climate which was occurred by the emission of carbon dioxide [2]. An effort of global world to generate renewable energy is the best solution to overcome global warming and the crisis of energy demand [3]. Biomass refers to all unprocessed material which survive in the environment. It can be either plant or animal origin [4]. The sources of biomass are municipal solid waste, sugarcane, bamboo, corn, miscanthus, vegetable waste fruit waste, paper, cow dung, human excreta, rumen digesta. It is practical that the generated energy from biomass has no negative shock on the surroundings. Moreover, the cost of production process will be low in amount and make more profit as energy will be produced from readily and locally available substances. Individuals may select to comprise their food waste to produce a useful fertilizer. In 2010, 150 million tons' food waste produced across world [5]. The amount of total solid in food waste is 18-31% and water are 70-80% [6]. Vegetable and fruit waste is a biodegradable material found in large quantities from various sources such as domestic, industries, municipalities, and markets. On the other hand, Rumen digesta defines as undigested animal waste which store into stomach of animal. There are various types of method available to convert waste into biogas. Anaerobic digestion is known as a fruitful left-over thing's treatment method because organic matter in food waste and rumen digesta are suitable for anaerobic microbial growth. Recycling of these wastes to produce biogas provides some energy and can have a significant effect on environment. Furthermore, biogas which is mainly CH_4, and CO_2 is the only cheap alternative renewable source of energy [7]. A four-stage mechanism is now widely accepted. There are four

pivotal steps of anaerobic digestion involve hydrolysis, acidogenesis, acetogenesis and methanogenesis in Fig. 1. Organic carbon is mainly converted into carbon dioxide and methane in these steps [8]. Chemical reaction can narrate the complete process where organic material is biochemically converted into their monomers, such as, glucose into carbon dioxide (CO_2) and methane (CH_4) by the anaerobic microorganisms.

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4 \qquad (1)$$
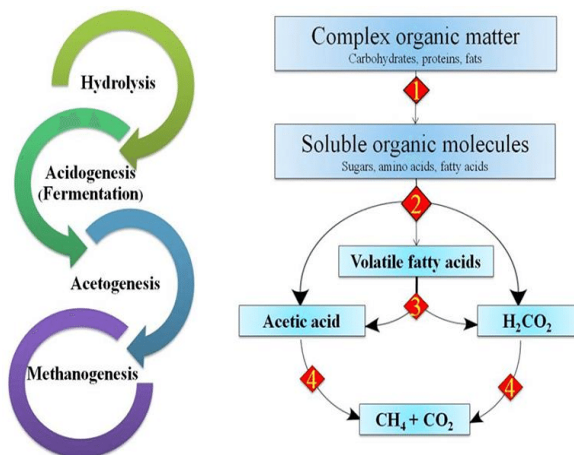
The process is shown below by diagram:

Fig. 1. Anaerobic digestion mechanism.

Numerous studies are conducted on the generation of biogas from cow dung, solid waste, fruit waste. But there are few reports are available on rumen digesta fermentation. Digestion of cow waste: fruit waste, cow waste: vegetable waste and vegetable waste: fruit waste in the ratio of 0.50:0.50, 0.75:0.25, 0.50:0.50 respectively produced the highest cumulative biogas 836, 811 and 756 mL/g VS [9]. An experiment was investigated to grasp the potentiality of biogas production from slaughterhouse waste and located that the ratio of 75% slaughterhouse waste and 25% cow dung is the best for biogas production [10]. There is no need to add nutrient or chemicals to generate biogas when fruit waste, vegetable waste and cow manure are blended [11].

The motive of this experiment is to grasp the comparison effect of mixture of waste (rumen digesta, fruit and vegetable waste) for biogas production. Six different ratios of sample were examined to know the optimum mixing ratios for production of biogas. Also, this paper focus on to control environmental pollution by recycling these waste.

II. Materials and Methods

Suitable method, fermented materials and design for collecting valid data is chosen through careful analysis.

A. Collection of Raw Materials

Three digestible waste materials (e.g. Rumen digesta, vegetable and fruit waste) were collected from different places. Rotted vegetables and fruits waste were collected from market and other houses. The vegetable waste consisted of potato, capsicum, cucumbers, onions, radish, cauliflower, carrot and leaf vegetables. Fruit wastes were apple, banana, papaya. Rumen digesta (cow and goat rumen waste) was gathered from different slaughterhouses. Cow rumen and goat rumen digesta were collected from slaughterhouse.

B. Preparation of Sample

Two trials of the experiments were studied to know the comparison effect of different mixing ratios of rumen digesta: vegetable waste: fruit waste. Total nine types of samples were made and designated as R1, R2, R3, R4, R5 and R6. To prepare sample, at first, weight of raw materials was taken. Rumen digesta, vegetable and fruit waste was mixed with a stirring rod at different mixing ratios to get the contact of each waste to achieve homogenous condition. The ratio of rumen digesta, vegetable and fruit waste and quantity of raw materials (gram) used in reactors are shown in table-I. Blended materials were mingled with water at the ratio of 1:1 (w/w). Blood from slaughterhouse was mixed with sample as blood contain active bacteria. pH of slurry before and after retention time and temperature was recorded during experiment time as shown in Table II. Anaerobic digestion procedure was conducted with laboratory scale batch digesters of 3000 mL working volume. 80% of digester that means 2400 mL was filled with prepared material.

TABLE I: WEIGHT OF PREPARED SAMPLE FOR CO-DIGESTION

Beaker	Ratio	Rumen Digesta (g)	Vegetable Waste (g)	Fruit Waste (g)	Water (mL)	Total Weight (g)
R1	1:1:2	300	300	600	1200	2400
R2	1:2:1	300	600	300	1200	2400
R3	1:1.5:1.5	300	450	450	1200	2400
R4	1:0.5:0.5	600	300	300	1200	2400
R5	1:2:2	240	480	480	1200	2400
R6	1.5:1.5:1	450	450	300	1200	2400

TABLE II: PH AND TEMPERATURE OF PREPARED SAMPLE

Reactor	p^H Before	p^H After	Change during Digestion	Temperature (°C)	Biogas Production (mL)
R1	6.5	6.6	0.1	28	502
R2	5.8	6.0	0.2	27.5	447
R3	6.4	6.5	0.1	27.5	441
R4	6.7	7	0.3	28	523
R5	6.8	7.8	1	28.5	791
R6	6.2	6.5	0.3	26.8	409

C. Experimental Setup

Laboratory based batch type experimental arrangement was set by using capacity of $3000ml$ three flask digester, one $1500mL$ water-cum-gas chamber flask along with one $1500ml$ water collector flask for every supervision. 12mm diameter plastic hose pipe used to connect flask digester with water-cum-gas chamber. Tube was operated to allow generated product to pass from digester to water-cum-gas chamber. Furthermore, tube of 10 mm diameter was applied to connect the water-cum-gas chamber with the water collector flask. These two flasks was connected so that same proportion of water can be transferred into water collector when generated bioenergy started to develop pressure on the water-cum-gas chamber. The amount of water replaced from the flask was equal to the amount of bioenergy produced. The water collector flask was set at an appropriate height to provide a desirable pressure to the gas outlet by water displacement. The gas collected pipe was connected together with tube made by glass and opposite side of the pipe linked with water and gas collected flask. Displaced water collected flask was joined by inserting hose pipe on the upper portion of the gas and water collected chamber. A valve was used to control gas flow from the digester. The experimental set up is shown a schematic diagram in Fig. 2.
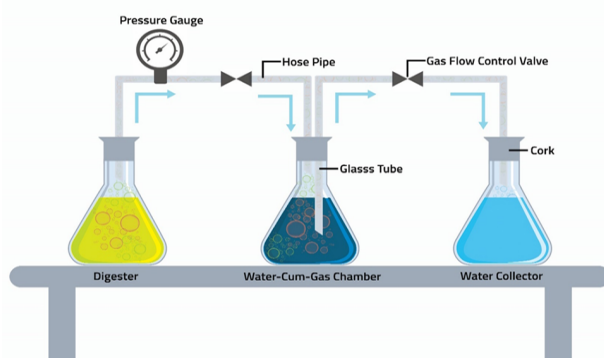

Fig. 2. A typical diagrammatic setup for biogas generation .

D. Observation

Six supervisions were done within two trial. Each trial comprised of three different observations. Investigation started immediately after finishing the filling of digester with different mixing ratios of raw materials. The digesters were left for 30 days so that the organic load could degraded by micro-organism. Gas was started to produce from first operating day, and it was almost finished at 27/28th digestion day. Temperature was recorded daily. The temperature was varied from 25°C to 35°C during the study period.

E. Measurement of Biogas

The biogas generated from each of the sample in the 3000 mL flask was estimated by water displacement method. As the biogas generates continuously, water is displaced into the water collector flask due to the pressure of produced biogas. This procedure is known as water-displacement technique. During the measurement of production, the control on the digester was released so that produced gas could flow into water collector. Experimented data was gathered in the same time (12 pm) every day from the selected experimental lab.

F. Analytical Method

pH meter which is originated by HANNA Instruments, Inc. Romania (HI98107) was used to measure pH of samples. Daily temperature of study period as well as the daily ambient temperature of the environment was measured by Thermometer (TP300, China). Temperature range of TP300 thermometer is -50°C ~ +300°C.

III. RESULTS

This experiment was conducted in laboratory and careful observation was done to record data of each trial. Data was recorded by water displacement method.

A. Biogas Production Profile

The production of biogas from rumen digesta, vegetable waste and fruit waste at mixing ratios of 1:1:2 which is designated as R_1 is represented in figure 3. The graph shows that the hydraulic retention period was 30 days and production started from 3rd day as materials began to decompose. The rate gradually increased from 3rd to 12th day. Then it production remains same on next day and again the rate increased from 14th day to 17th day. On 17th day production was in peak point and it was 35 mL. After that generation became slow and started to decrease due to temperature fall. The average gas production was 17 mL/day.
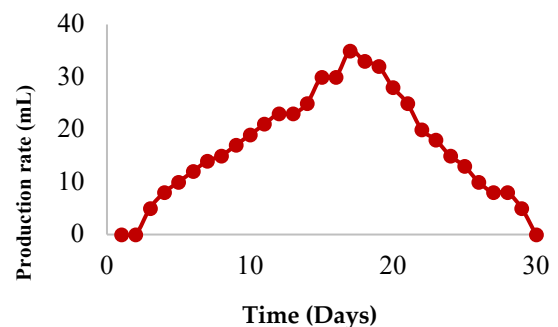

Fig. 3. Biogas production from ratio (1:1:2).

Fig. 4 represents the production rate from raw materials at mixing ratios of 1:2:1 which is denoted by R_2. Under 30 retention period, generation began from 3rd day and gradually increased to 15th day. 33 mL/day was recorded as maximum production of biogas which was produced at 14th and 15th day. After 15th day of digestion period production started to fall due to temperature. From 28th to 30th the generation was nil. The average rate of production was 15mL/day.
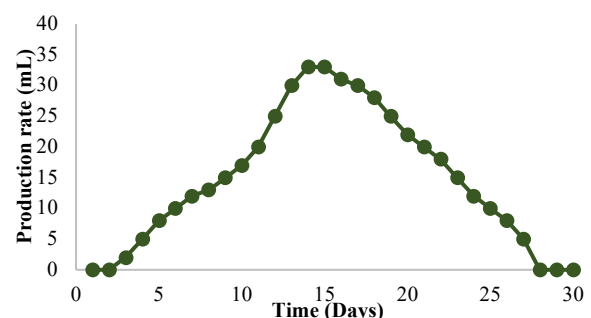

Fig. 4. Biogas production from ratio (1:2:1).

The biogas yield from rumen digesta, vegetable waste and fruit waste at mixing ratios of 1:1.5:1.5 which is designated as R_3 is represented in Fig. 5. Generation started from 3rd day and amount was 1 mL which is very low. Production started to increase gradually from that day to 16th day.
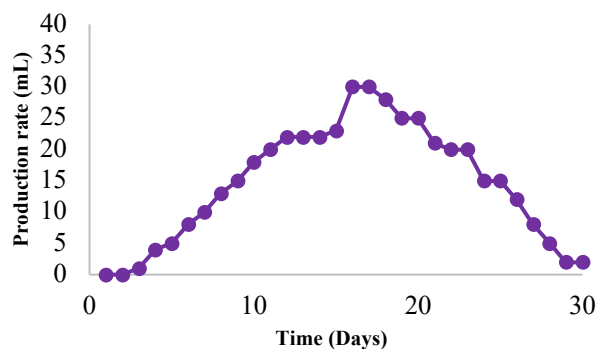

Fig. 5. Biogas production from ratio (1:1.5:1.5).

On the 17th day production remains same. The result of the gas production shows maximum on 16th and 17th day with the gas generation of 30 mL. Then started to decrease from next day due to temperature fall and reached 2 mL on 29th day. The rate followed same by next day. The average rate of production was 14 mL/day.

Fig. 6 represents the graph for the production of biogas from rumen digesta, vegetable waste and fruit waste at the mixing ratio of 1:0.5:0.5 which is denoted as R_4. In this trial, production starts from the first day and it started to increase gradually due to desired temperature. The highest production was recorded on 11th day and it was 40 mL which is high compared to previous trial. After 11th day, production rate started to decrease. The lowest data was recorded 5 mL on 26th and 27th day. After that gas was not produced in this trial.
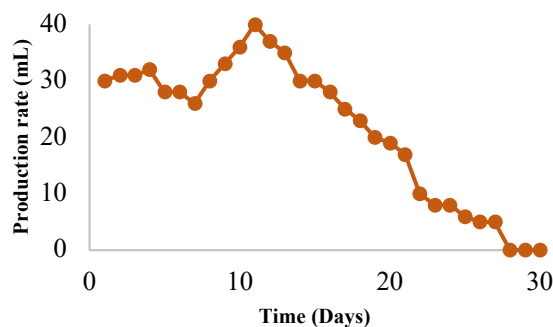

Fig. 6. Biogas production from ratio (1:0.5:0.5).

The generation rate of biogas from rumen digesta, vegetable waste and fruit waste at mixing ratio 1:2:2 which is designated as R_5 is shown in Fig. 7. The highest data of production was recorded in this ratio. Production started from the second day and it was 5 mL. Generation rate gradually increased till 12th day and maximum production recorded on that day which was 50mL. After that day production started to decrease gradually due to temperature fall. The lowest data recorded was 2 mL on 30th day. The average rate of production was 25 mL/day.
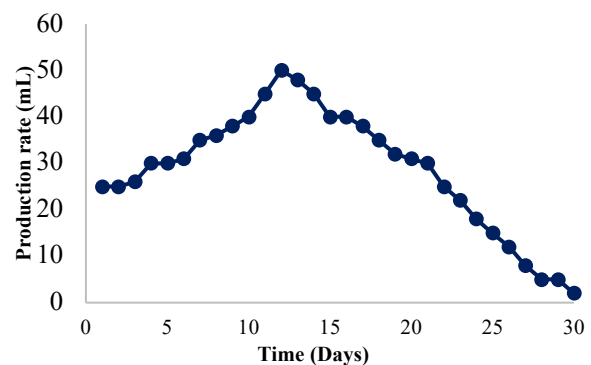

Fig. 7. Biogas production from ratio (1:2:2).

Fig. 8 demonstrates the graph for the production of biogas from rumen digesta, vegetable waste and fruit waste at the mixing ratio of 1.5:1.5:1 which is R_6. Generation started from 1st day. The amount was 3mL which was so little. Production rate decreased on 2nd and 3rd day rather than increased. The rate gradually raised from 4th day to 7th day and maximum data recorded was on that day which was 35 mL. Generation rate was not so high due to temperature fluctuation and P^H of sample. The lowest data was 1 mL which was recorded on 29th day. The average production rate was 14 mL per day.
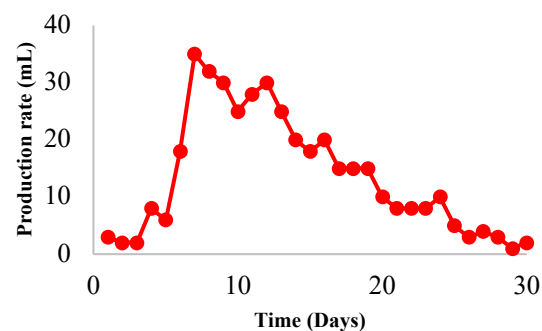

Fig. 8. Biogas production from ratio (1.5:1.5:1).

B. Comparability results of Biogas Generation

Fig. 9 represents variation in production of gas after every 10 days. The graph also reveals that the production rate of each mixture of first trial was in peak point at 2nd 10 days (11-20 days) due to the full decomposition of raw material. Among these three mixtures, the highest average rate of 10 days was found 28 mL from first mixture which is denoted by R_1 at the ratio of rumen digesta: vegetable waste: fruit waste (1:1:2). The rate of yield was low between 1-10 days compared with 2nd and 3rd 10 days.
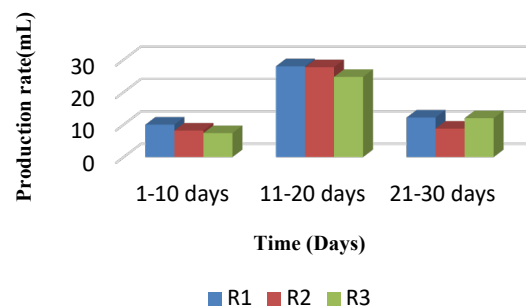

Fig. 9. Observation of gas production at interval of 10 days (1st Trial).

Fig. 10 illustrates variation in production of gas (2nd Trial) after every 10 days. The graph also shows that the generation rate of two mixtures which is denoted by R_5 and R_6 was in peak point at 2nd 10 days (11-20 days) due to the full decomposition of raw material. Among these three mixtures, the highest average rate of 10 days was found 40.4 mL from second mixture which is denoted by R_5 at the ratio of rumen digesta: vegetable waste: fruit waste (1:2:2). The rate of yield was low between 21-30 days compared with other days.
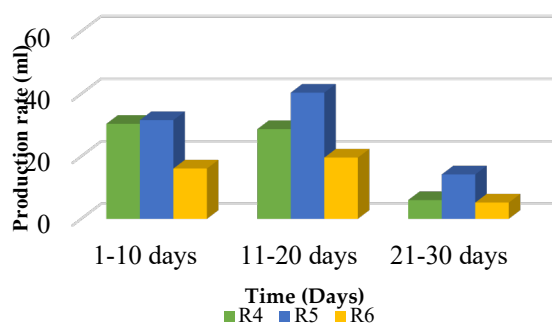

Fig. 10. Observation of gas production at interval of 10 days (2nd Trial).

C. Accumulate Gas Production (mL)

Fig. 11 represents the accumulative gas production from different mixing ratios of rumen digesta, vegetable waste and fruit waste. The line graph reveals that cumulative production was 502 mL, 447 mL, 441 mL from rumen digesta, vegetable waste and fruit waste respectively. At this trial highest production was found from raw material at the ratio of 1:1:2.
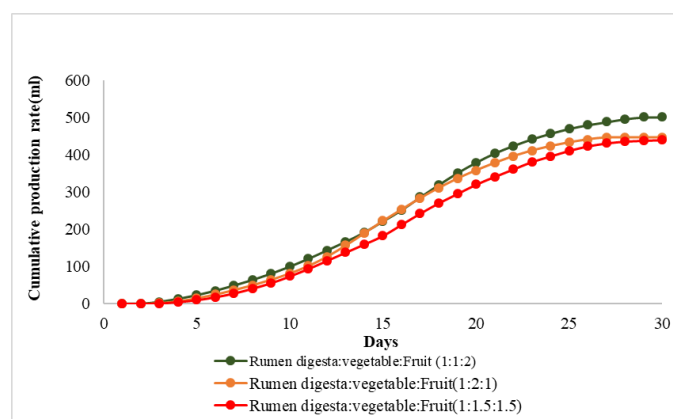

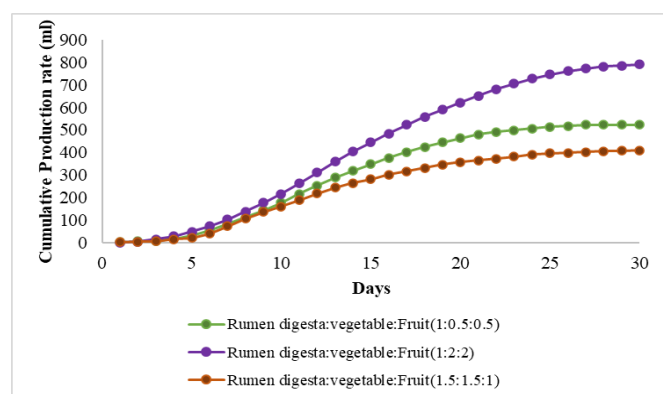Fig. 11. Cumulative production from 1st trial.

Fig. 12. Cumulative production from 2nd trial.

Fig. 12 demonstrates the accumulative biogas generation from different mixing ratios of rumen digesta, vegetable

waste and fruit waste. The figure reveals that cumulative production was 523 mL, 791 mL, 409 mL from rumen digesta, vegetable waste and fruit waste respectively. At this trial highest production observed from raw material at the mixing ratio of 1:2:2 which was 791 mL.

D. Effect of TS, VS and MC on biogas yield

This research work also observed different concentrations of percentage total solid (%TS) and percentage volatile solid (%VS) of different raw materials that were co digested and their effect on amount of biogas production in order to determine suitable value of %TS and %VS for optimum biogas production. The appropriate analysis of produced biogas against %TS, %VS and %MC is shown in following Table III.

TABLE III: APPROPRIATE ANALYSIS OF BIOGAS YIELD WITH TOTAL SOLID, VOLATILE SOLID AND MOISTURE CONTENT

Sample	% Total Solid	% Volatile Solid	% Moisture Content	Cumulative Biogas Yield (mL)
R_1	8.9	78.4	92	502
R_2	8.5	67.6	85	447
R_3	6.85	59.5	82.9	441
R_4	10.0	90.8	88.5	650
R_5	10.3	93.5	91.5	862
R_6	3.5	57.3	80	409

From this table it is evident that biogas production rate increases with increasing rate of %TS, %VS and % moisture content and decreases with the decreasing rate of %TS, %VS and % moisture content. Percentage of total solid accumulation would no longer contribute to up warding biofuel generation after a certain period.

E. Temperature Profile

Fig. 13 represents daily temperature of each trial. Temperature was recorded during anaerobic digestion period. The temperature was in mesophilic range during trial. The highest temperature was 35°C and 33°C during 1st and 2nd trial respectively. The lowest temperature recorded 27°C and 26°C from 1st and 2nd trial respectively.
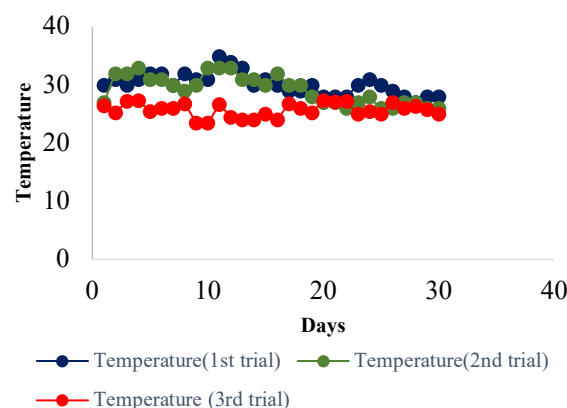

Fig. 13. Daily temperature digestion day

IV. DISCUSSION

The present study describes the production of biogas at different mixing ratios and about parameters of anaerobic digestion process. The parameters which observed in this

study are temperature, pH, %TS, %VS, %MC. Temperature is taken as an important factor for the production of biogas. The highest temperature (33°C) was observed in second trial at the 11th, 12th and 13th day. Production rate was also high in these days. Although 40°C temperature is optimum for maximum gas production, but in some cases, increase in biogas production occurs between the temperatures of 35°C and 40°C [12]. The Study [13] also shows that biogas production and methane was also increased with the increasing temperature. pH is a scale used to determine how acidic or basic a water-based solution is. The pH of mixtures of sample in this study was 6.5, 5.8, 6.4, 6.7, 6.8 and 6.2 for R_1, R_2, R_3, R_4, R_5 and R_6 respectively. The result showed that the sample which pH was 6.8 had the maximum biogas yield followed by the other samples. A research observed that the if the pH value increased from 5.5 to 7.5 when the CH_3COOH equivalent and COD concentration was reduced 88.1% and 18.3% respectively in the hydrolysate result in 58% CH_4 production in this experiment which is very similar comparison with the present study. [14]. In present study the concentration of TS was measured and recorded. According to result found on present study, cumulative biogas production increases with the increasing of %TS. After optimum % TS, production level did not raise with the increase of %TS rather it started to fall. In this study, highest cumulative biogas yield was recorded at 10.3 %TS. The result is similar with the result of a research [15] which showed that the reactor with 10% of total solid content yielded higher biogas compared with other reactors which was filled with material contain 5%, 15% and 20% TS.

V. CONCLUSION

Demand of energy and management of myriad biodegradable waste are cardinal problems faced by the world which is caused by the increasing trend of population and lack of proper planning of urbanization. To overcome this energy crisis, the best solution is to produce a renewable energy source. In this study nine different ratios of materials mixed under three trial. The cumulative production of biogas was 502, 447, 441, 523, 791 and 409 mL at the mixing ratios of 1:1:2, 1:2:1, 1:1.5:1.5, 1:0.5:0.5, 1:2:2 and 1.5:1.5:1 (RD: VW: FW) respectively. The result of the study shows that the purpose was achieved successfully. The maximum cumulative biogas produced from sample at the mixing ratios of 1:2:2 (RD: VW: FW) and production was 791 mL. The percentage of total solid, volatile solid and moisture content was also measured. The result shows that production rate changes proportionally with these parameters. The results obtained from this study could be used as a basis for designing large scale anaerobic digesters for treatment of rumen digesta, vegetable waste and fruit waste. Thus, successful implementation of this technique can contribute to control environmental pollution and mitigate energy crisis.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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