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BIOGAS PRODUCTION FROM THE CO-DIGESTION OF KITCHEN WASTE AND COW MANURE

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Abstract: Untreated and Unmanaged Kitchen waste from Domestic consumption, Restaurants, Catering services, Universities, etc. when disposed-off to the landfill or discarded to the surroundings then in return it pollute the environment. And methane emitted from their decomposition, contributes to the global climate change. Under MSW (Management and Handling) Rules, 2016 promulgated by MOEF, Govt. of India, these wastes are becoming difficult to manage and dispose-off using traditional means. Due to an increasing urbanization and awareness of the true economic, land scarcity for landfilling and environmental cost of the conventional land filling, recent interest is to develop technologies that can generate biogas from the kitchen wastes because of its high biodegradability and methane yield characteristic.The current project work focuses on the estimation of amount of Biogas generated and Methane and Carbon dioxide content in the biogas by varying the quantity of the Kitchen Waste and Cow Manure in an anaerobic condition. Also to study the continuous variation in the temperature and pH of the reactor throughout the process. First three Sets of the experiment consisting of Kitchen waste as Set1, cow manure as Set2 and co-digestion of Kitchen waste and Cow manure as Set3 were conducted at room temperature. And as per observation, Set3 yielded more biogas in comparison with other two sets. And then further four more Sets of Set3 were tested at a different ratios i.e. (KW:CM, 1:0 for Set1, 1:1 for Set2, 2:1 for Set3 and 3:1 for Set4) to observe the effect of the mixing ratio of Kitchen waste and Cow manure at room temperature and note down the variation of pH and Temperature throughout the process. And it was found that in case of cumulative production of methane, Set 4 gave the maximum value i.e. 318.76 ml and in terms of percentage, Set 2 gave the maximum value i.e. 68.40%. In Set 1, the biogas generation was quite high but the bio methane content was low and carbon dioxide was the prominent gas.

Keywords: Anaerobic Digestion (AD); Cow Manure (CM); hydraulic retention time (HRT); Kitchen Waste (KW); Municipal Solid Waste (MSW).

I. INTRODUCTION

According to a new United Nations data as of May 2018, 55% of the world's population lives in the urban areas, a proportion that is expected to increase to 68% by 2050, nearly 90% of this increase taking place in Asia and Africa,. By 2050, it is expected that India will have added 416 million urban dwellers. As a consequence to the increasing number of population and the improvement of living quality since the past many decades, the total amount of municipal solid waste in general and food waste in particular is continuously rising. As per the World Bank report, in 2016, the world's cities generated 2.01 billion tonnes of solid waste, amounting to a footprint of 0.74 kilograms per person per day. With rapid increase in population and urbanization, annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050.

As per census 2011 the growth rate of Arunachal Pradesh is 26.03% which is more than many of northeast states of India. This fairly high growth rate of urbanization of the State has led to various environmental problems like solid waste accumulation. The urban population in the last 10 years has raised by 22.94 percent. At present, the generation of huge amount of solid wastes has become a burning question in most of the urban areas. Itanagar, the capital of Arunachal Pradesh, is also facing serious threat to its evergreen atmosphere due to the prevailing scenario of increasing level of solid waste generation (*Debnath, 2013*).

The food waste is a highly desirable substrate for anaerobic digesters with regards to its high biodegradability and methane yield (*Ruihong Zhang, 2007*). Pretreatment of kitchen waste or food waste anaerobically prior to landfill disposal or composting not only provide us biogas as a fuel or its byproduct as a fertilizer but also helps in reduction of masses and volume, inactivation of biological and biochemical processes in order to avoid landfill-gas, odor emissions, methane generation and decrease in area required for the landfill. Therefore, anaerobic digestion of kitchen waste can be considered as an alternative option to improve the environment condition caused by kitchen waste and lessen our dependents on the wood, coal and petroleum by using an environmentally-friendly resource of methane and its byproduct as fertilizer.

II. OBJECTIVES OF THE STUDY

1. Comparison on biogas production from kitchen waste (KW), cow manure (CM) and KW with CM at room temperature.
2. Behavior and performance of the digester at various ratio of the substrates (KW:CM) with particular regard to the gas production rate.
3. To find out the hydraulic retention time (HRT) at which maximum biogas is yielded.
4. Comprehensive study of various environmental factors like temperature, pH affecting the gas production rate.

III. MATERIALS AND METHODS

Waste collection and processing

KW was collected from various hostels of North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli and was processed in digesters to produce biogas through AD. CM was collected from NERIST campus. In kitchen waste, rice and vegetables were nearly about 90% to 95%. Eggs shells, fruits etc. were relatively low. After carefully removing the plastic bags, bones, and inorganic residues, wastes were cut into small size by mixer grinder in order to reduce the size to get efficient biogas production.

Experimental set-up in laboratory

In the batch reactor system of anaerobic co-digestion of the kitchen waste and cow manure, first three numbers of two liter bio reactor has been used. And subsequently four numbers of two liter bio reactor were set up as shown in Fig.1 and fig. 2 with varying the quantity of KW and CM.

In the first three sets of the experiment, set-1 consist of 100gm of KW, set-2 consist of 100gm of KW and 25gm of CM and set-3 consist of 100gm of CM. And in subsequent four sets, each reactor consisted of the mixed of KW and CM in the ratios of 1:0, 1:1, 2:1 and 3:1 and tap water to make 1 liter solution. And nitrogen gas N_2 is flushed in reactor for three minutes in order to obtain anaerobic condition in the reactors.

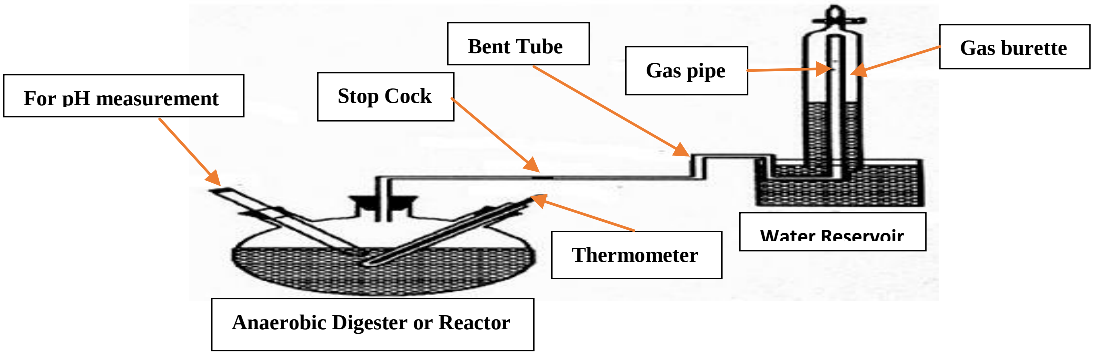

Fig. 1. *Schematic diagram of the lab-scale experimental set-up.*

Fig. 2. *Sample 1 Batch reactor 1:0 (KW:CM).*

IV. RESULTS AND DISCUSSIONS

4.1 First three sets: KW, CM and KW + CM

First three sets of experiment were done to study, which among the three sets produce more biogas and leads to the further experimentation of that particular set. The volume measured as shown in the table 1(a) are the value as observed in the burette. The generation of Biogas studied for 10 day time period, taking 10 readings at fixed interval as shown below:

Table 1(a). Comparison on biogas production (ml) at room temperature.

Days	Volume of biogas produced(ml)		
	KW (Kitchen Waste) (100gm)	CM (Cow Manure) (100gm)	KW and CM (100gm, KW and 25gm, CM)
1	0	0	0
2	0	0	0
3	35.6	5	56
4	56	27	70
5	49	45	75.1

6	46.4	40	45
7	28.1	30	40
8	19.5	20	37
9	5	10	25
10	1	5	20

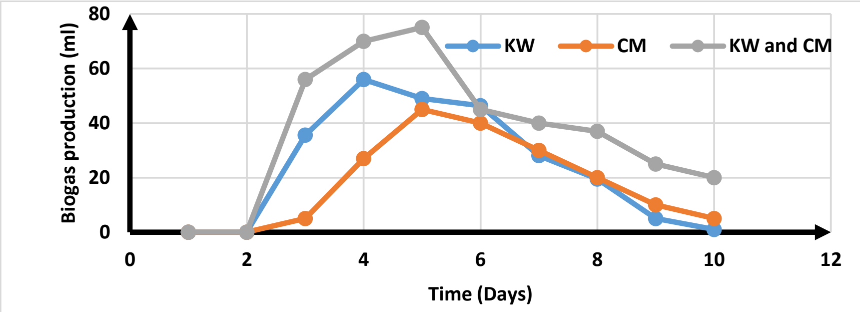

Fig. 3. Comparison on biogas production (ml) at room temperature.

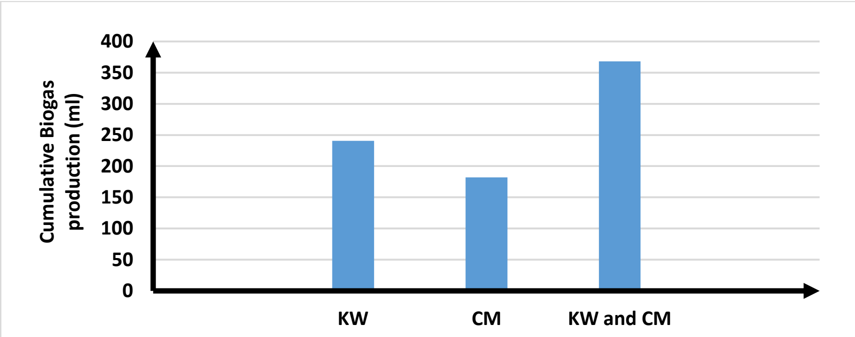

Fig. 4. Comparison on cumulative biogas production (ml) at room temperature.

Observation and Analysis:

Table 1(a) shows the comparison on biogas production from KW, CM and co-digestion of KW with CM at room temperature. A graph was plotted between the gas production rate of KW, CM and co-digestion of KW and CM vs Time as shown in the figure 3 and 4. It is evident from the graph that the results of co-digestion of kitchen waste with cow manure was more as compared to the biogas production rate of cow manure and kitchen waste taken individually.

4.2 Subsequent four sets in the ratio of (KW:CM, 1:0, 2:1, 3:1 and 4:1)

Table 1(b). Different Parameters of biogas obtained from set -1

Parameters for set 1 (KW:CM, 1:0)									
Days	Volume of biogas produced			% Composition in biogas			**Temp °C**	**pH**	**Pressure inside (kN/m^2)**
	V_0 (ml)	**h** (mm)	V_{act} (ml)	CH_4 %	CH_4 (ml)	CO_2 %			
0	0.00	100	0.00	0.00	0.00	0.00	24.00	7.20	100.324
3	71.20	28.80	71.00	1.5	1.07	38.90	23.00	5.70	101.042
6	112.00	0.00	112.00	11.9	13.33	50.50	22.00	5.60	101.325
9	141.40	0.00	141.40	28.30	40.02	42.80	22.60	4.70	101.325
12	98.00	2.00	97.98	31.20	30.57	32.20	22.20	5.60	101.305
15	92.80	7.20	92.73	32.00	29.67	24.10	22.80	6.60	101.254
18	83.00	17.00	82.86	26.00	21.54	19.60	23.00	6.90	101.158
21	53.00	47.00	52.76	21.40	11.29	20.30	22.60	7.20	100.864
24	56.20	43.80	55.96	16.20	9.07	18.30	22.00	7.00	100.895
27	39.00	61.00	38.77	14.00	5.43	16.00	22.40	6.80	100.727

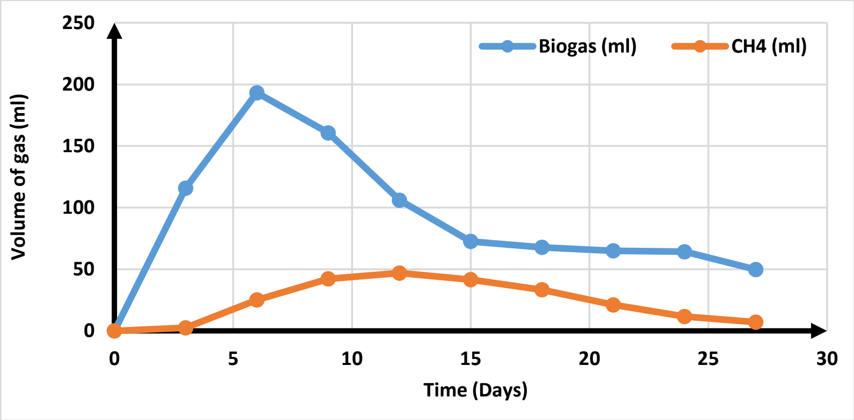

Fig.5. *Variation of Biogas and CH_4 with Time (SET-1).*

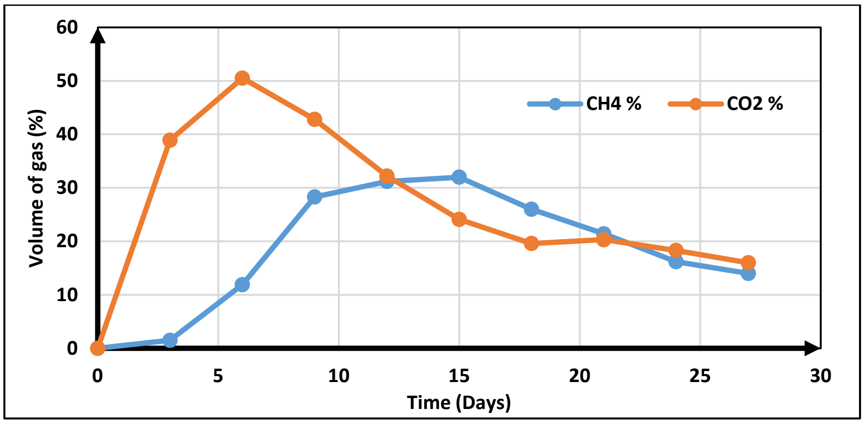

Fig 6. *Variation in percentage volume of CH_4 and CO_2 with Time (SET-1).*

Table 1(c). Parameter of Set 2

Parameters for Set 2 (KW:CM, 1:1)									
Days	Volume of biogas produced			% Composition in biogas			**Temp °C**	**pH**	**Pressure inside (kN/m^2)**
	V_0 (ml)	**h** (mm)	V_{act} (ml)	CH_4 %	CH_4 (ml)	CO_2 %			
0	0.00	100	0.00	0.00	0.00	0.00	24.00	7.23	100.324
3	112.00	0.00	112.00	6.74	7.55	24.30	23.00	6.70	101.325
6	140.00	0.00	140.00	29.00	40.60	41.80	22.00	5.90	101.325
9	150.20	0.00	150.20	46.43	69.74	52.40	22.60	5.50	101.325
12	98.00	2.00	97.98	57.90	56.73	42.80	22.20	6.80	101.305
15	85.00	15.00	84.88	68.40	58.06	30.00	22.80	7.10	101.178
18	67.00	33.00	66.79	32.77	21.89	16.32	23.00	7.80	101.001
21	61.00	39.00	60.77	19.69	11.97	10.99	22.60	6.00	100.942
24	59.00	41.00	58.77	13.53	7.95	9.14	22.00	6.10	100.923
27	45.00	45.00	44.80	10.96	4.91	8.43	22.40	6.20	100.883

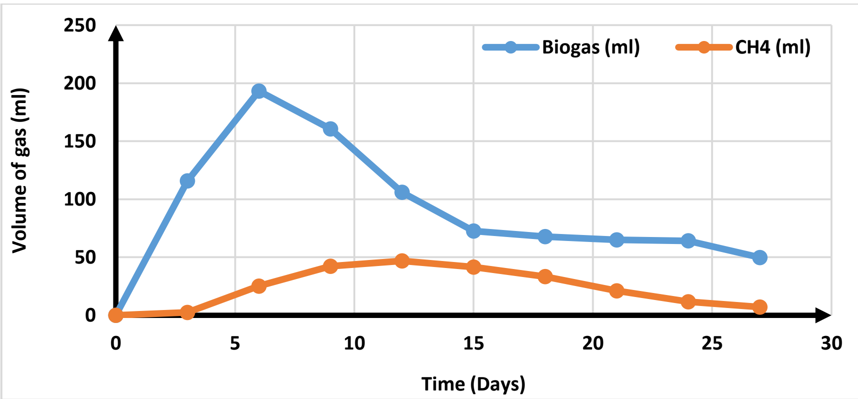

Fig.7. *Variation of Biogas and CH_4 with Time (SET-2).*

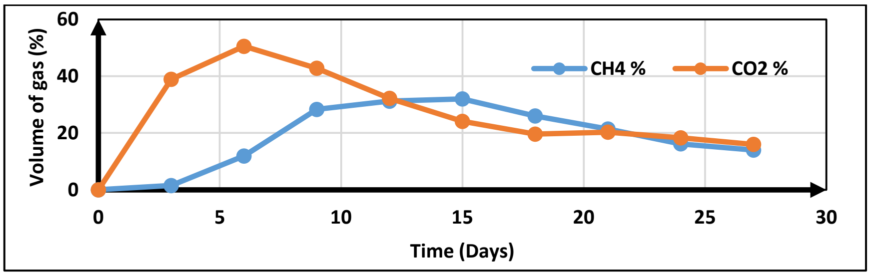

Fig 8. *Variation in percentage volume of CH_4 and CO_2 with Time (SET-2).*

Table 1(d). Parameter of Set 3

Parameters for Set 3 (KW:CM, 2:1)									
Days	Volume of biogas produced			% Composition in biogas			**Temp °C**	**pH**	**Pressure inside (kN/m^2)**
	V_0 (ml)	**h** (mm)	V_{act} (ml)	CH_4 %	CH_4 (ml)	CO_2 %			
0	0.00	100	0.00	0.00	0.00	0.00	24.00	7.40	100.324
3	115.80	0.00	115.80	2.10	2.43	21.60	23.00	6.40	101.325
6	193.20	0.00	193.20	13.00	25.12	32.30	22.00	6.00	101.325
9	160.60	0.00	160.60	26.30	42.24	44.50	22.60	5.70	101.325
12	106.00	0.00	106.00	44.20	46.85	32.20	22.20	6.60	101.325
15	72.80	27.20	72.61	57.20	41.53	28.60	22.80	7.00	101.058
18	68.00	32.00	67.79	49.20	33.35	23.20	23.00	7.50	101.011
21	65.20	34.80	64.98	32.40	21.05	21.30	22.60	6.00	100.984
24	64.40	35.6	64.18	18.10	11.62	20.20	22.00	6.10	100.976
27	50.00	50.00	49.76	14.20	7.07	19.40	22.40	5.60	100.834

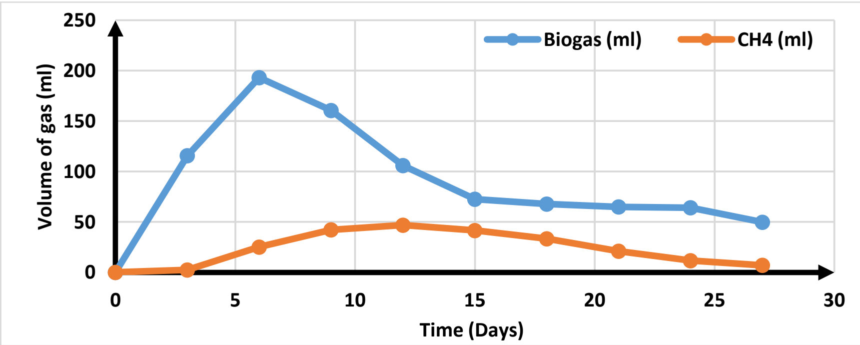

Fig 9. *Variation of Biogas with Time (SET-3).*

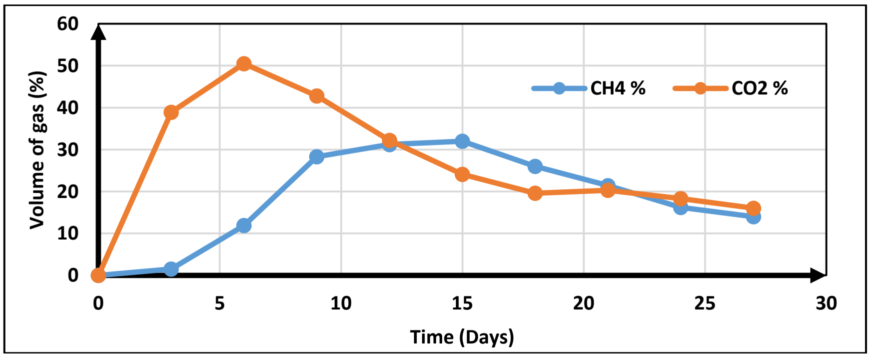

Fig 10. *Variation in percentage volume of CH_4 and CO_2 with Time (SET-3).*

Table 1(e). Parameter of Set 4

Parameters for Set 4 (KW:CM, 3:1)									
Days	Volume of biogas produced			% Composition in biogas			**Temp °C**	**pH**	**Pressure inside (kN/m^2)**
	V_0 (ml)	**h** (mm)	V_{act} (ml)	CH_4 %	CH_4 (ml)	CO_2 %			
0	0.00	100	0.00	0.00	0.00	0.00	24.00	7.50	100.324
3	67.80	32.20	67.59	1.30	0.88	18.90	23.00	6.10	101.009

6	155.00	0.00	155.00	21.60	33.48	29.00	22.00	5.60	101.325
9	170.00	0.00	170.00	38.20	64.94	48.60	22.60	6.30	101.325
12	174.00	0.00	174.00	55.10	95.87	32.30	22.20	7.00	101.325
15	87.00	13.00	86.89	45.40	39.45	27.80	22.80	6.80	101.197
18	77.60	22.40	77.43	42.30	32.75	25.20	23.00	6.20	101.105
21	72.00	28.00	71.80	37.90	27.21	24.20	22.60	6.10	101.050
24	76.00	24.00	75.82	18.30	13.88	20.20	22.00	5.90	101.089
27	68.00	32.00	67.79	15.20	10.30	21.30	22.40	5.60	101.011

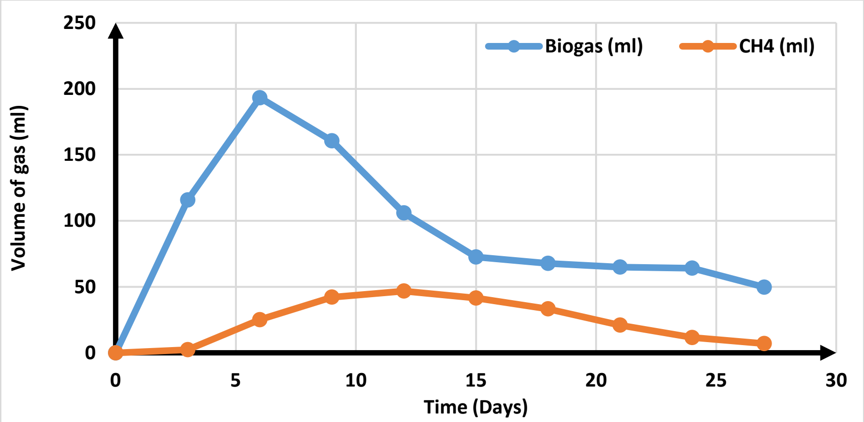

Fig 11. *Variation of Biogas with Time (SET-4).*

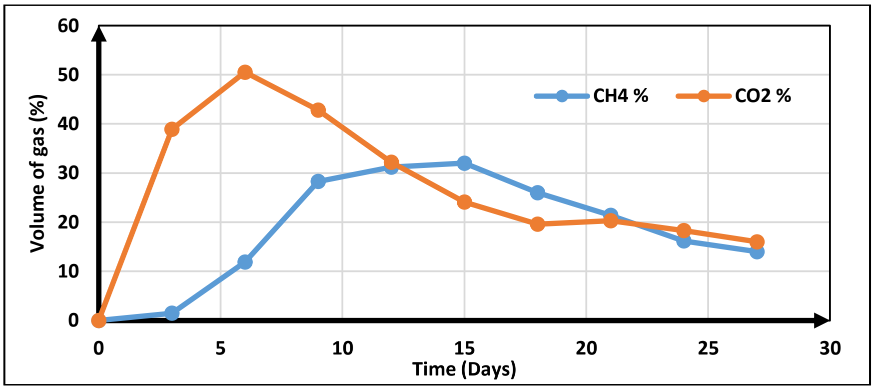

Fig 12. *Variation in percentage volume of CH_4 and CO_2 with Time (SET-4).*

4.3 Comparison of CH_4 and Biogas production rate in Four Set-ups

Among the four sets, the volume of bio methane produced in the Set 4 was maximum in terms of cumulative production i.e. 318.76 ml, but in terms of percentage (%) taken for individual readings, Set 2 gives the highest value i.e. 68.40% which is as shown in the Fig. 13 and 14. Also as the Set 1 contained only KW, thus because of lacking in bacteria seed (methanogenic bacteria) their degradation rate was slow which leads to the least biogas generation and lowest methane content in comparison with other three sets. In Set 1 prominent gas was CO_2.

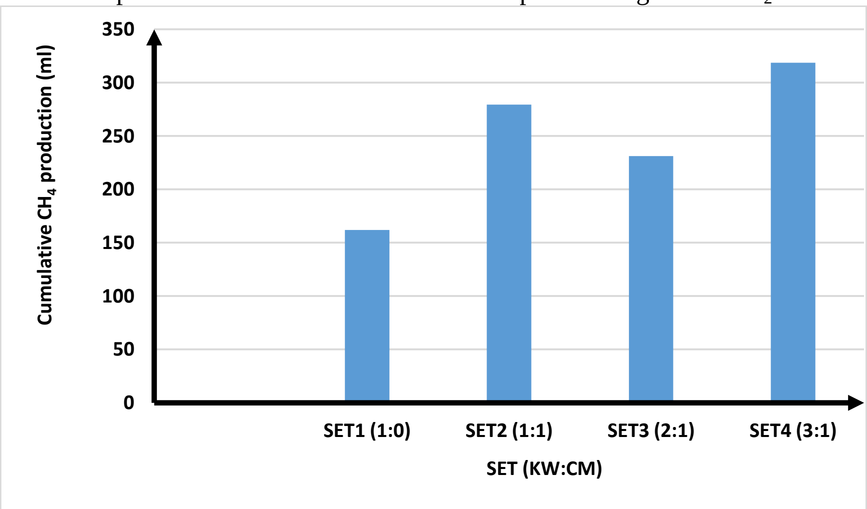

Fig 13. *Comparison of CH_4 production rate in four set up.*

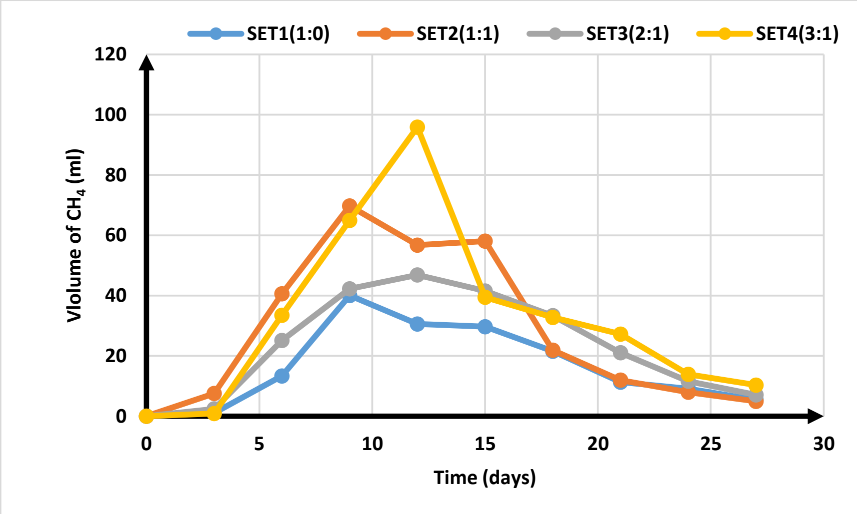

Fig 14. *Comparison of CH_4 production rate in four set up.*

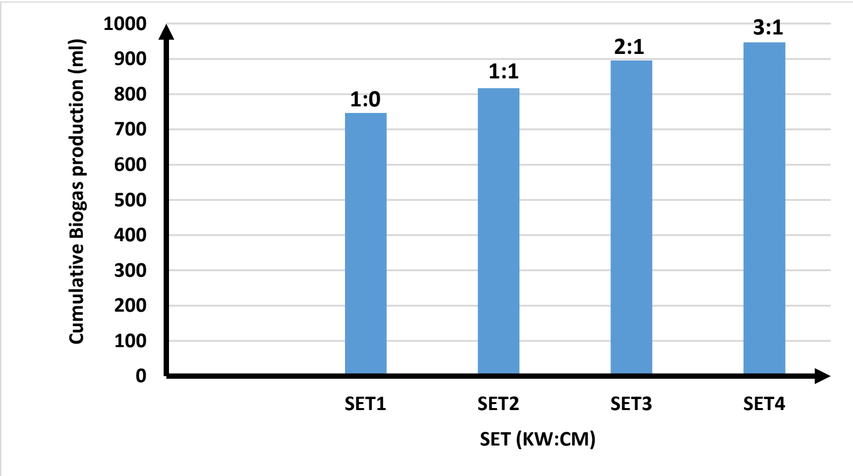

Fig 15. *Comparison of cumulative biogas production rate in four set up.*

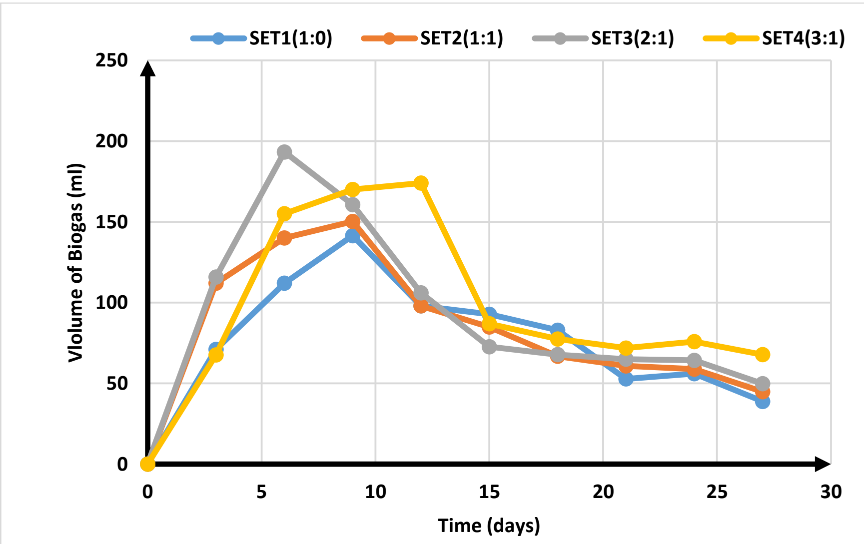

Fig 16. *Comparison of biogas production rate in four set up.*

Table 1(f). Cumulative percentage content of different gases

Total volume of gas generated during the entire time period			
Set	**Biogas (ml)**	**CH_4 (ml)**	**Highest CH_4 % of the set**
Set 1	745.06	161.99	32.00
Set 2	816.19	279.40	68.40
Set 3	894.92	231.26	57.20
Set 4	946.32	318.76	55.10

From the table 1(f) it is evident that in terms of cumulative value, set 4 generated the maximum amount of methane which is 318.76 ml of the total biogas generated during the entire experimentation period. Whereas in terms of percentage, the set 2 gives the highest value i.e. 68.40%. And the set 1 recorded the lowest value for both the cases i.e. 161.99 ml and 32%. It was notice that prominent gas in case of set 1 was carbon dioxide.

V. CONCLUSION

The study has shown that the anaerobic co-digestion of kitchen waste and cow manure is a feasible process. Furthermore, anaerobic co-digestion of kitchen waste and cow manure is a viable alternative for recovering energy in the form of biogas with 45-70 % methane content while at the same time abating environmental pollution. From the results of all the 4 sets, it was found that in case of cumulative production of methane, Set 4 gave the maximum value i.e. 318.76 ml and in terms of percentage, Set 2 gave the maximum value i.e. 68.40%. It was 58.058 ml out of 84.88 ml of biogas produced. In Set 1, the biogas generation was quite high but the bio methane content was low and carbon dioxide was the prominent gas. Hence, by comparing the results of all the 4 sets in terms of bio-methane content and biogas production, set 4 with ratio 3:1 (KW:CM) was found to be the most efficient bio reactor in methane generation.

The pH was observed to fluctuate during the entire observation period. It first becomes acidic and then it increases to basic stage. The biogas start generating at the pH around 6.5 and continues it reaches the maximum and then it lowers down, which results in lower generation rate of methane. The optimum pH for the high rate of generation of methane for all the sets was found to be around 6.8 to 7.5.

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