Effect of Different Mixtures of Kitchen Waste and Cattle Dung on Biogas Production

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Abstract- **Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment. Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic microorganisms. Different mixtures of kitchen waste and cattle dung were tried for biogas production. Among all these methods anaerobic digestion is a best way of treating any biodegradable waste like kitchen waste since during this process energy is produced in the form of biogas. The reactors were operated in batch mode for 35 days. It was found that reactor with 1:1 ratio of kitchen waste and cattle dung produced nearly same amount of methane (2158 ml) as the reactor with 0:1 cattle dung (4005 ml) in 15 days. However, the reactor with solid cattle dung alone with no water produced maximum biogas production (4015ml) among all the reactors operated in the present study. This showed that there is feasibility of using kitchen waste which is produced in large quantities in residential area along with cattle dung for biogas production. Even the farmers in the village with less amount of cattle dung can use kitchen waste as its substitute. This will solve their problem of less substrate as well as make our environment pollution free.**

Keywords: KW- Kitchen Waste, CD- Cattle Dung, TS- Total Solids, VS- Volatile Solids, R- Reactor, L- Litre, ml- Millilitre, dm- Decimeter

I. INTRODUCTION

A. General Background

During the past two decades, developing countries and particularly India has witnessed increased level of waste generation due to population explosion, increased agricultural activities, and the growth of industries. Consequently, there is an intense scrutiny of possible alternative of solid waste utilization through biogas production using organic residues, which includes poultry droppings, cattle dung, and kitchen wastes. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment. Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic microorganisms. The process of anaerobic digestion has been practiced for decades in developing countries. The first anaerobic digester was built in Bombay, India in 1859. Since then, the technology has become widespread throughout Asia. As early as 1975, China and India implemented large government-backed schemes for adaptation of small biogas plants (typically 6–8 m^3 digester size) used in rural households for cooking and lighting.

B. Justification

Waste includes all items that people no longer have any use for, which they either intend to get rid of or have already discarded. Additionally, wastes are such items which people are required to discard, because of their hazardous properties. Solid waste, a nuisance in today's world is causing environmental problem. Solid waste can be classified into different types depending on their source i.e. household waste is general classified as municipal waste and Biomedical waste as infectious waste. Kitchen waste is one of the various types of solid wastes generated by today's society.

Accumulation of wastes due to its improper disposal is a major problem in our country. The recent Surat plague epidemic is an indication. Population in India has been growing at the rate of 1.7%. With this increase, there has also been an increase in the amount of wastes being produced especially in the cities. Every person, on an average generates about 400 to 500 grams of wastes per day. At this rate, in a city of about 10 lakh people, around 500 tonnes of wastes is being produced every day.

In the absence of proper solid waste management, this waste lies littered on our streets, road corners and improperly disposed of in vacant land. All of these are serious health hazards apart from being eyesores. If they are not cleared regularly at the earliest, they invite host of problems like increasing numbers of insect vectors like flies, mosquitoes, etc., scavengers such as stray dogs, pigs and rats which spread dangerous diseases. It also generates bad odour and causes pollution

Kitchen waste and cattle dung are biodegradable wastes which can be decomposed by the natural processes and converted into the elemental form. Since kitchen waste if left untreated will create problem for our environment. So there is need to treat it. There can be different ways of treating biodegradable wastes like aerobic digestion, composting, anaerobic digestion etc.

Among all these methods anaerobic digestion is a best way of treating any biodegradable waste like kitchen waste since during this process energy is produced in the form of biogas. Biogas, as is known can be used for different purposes like cooking, running water pumps, engines, for generating electricity etc. The slurry produced from a biogas plant can be a very good fertilizer for our agricultural fields. In addition, it will provide a healthy, clean and smoke free environment in rural kitchens. This will remove the drudgery of rural women who have to suffer while working on traditional smoky chullas. Kitchen waste and cattle dung both are organic in nature. So both of them can be used for biogas production. Therefore to study the different feasibility of substituting cattle dung with kitchen waste.

C. Review of Literature

Bouallagui et al. (2003) tested a semi-continuously mixed mesophilic tubular anaerobic digester for the conversion of fruit and vegetable waste (FVW) into biogas. The effect of hydraulic retention time (HRT) and the feed concentration on the extent of the degradation of the waste was examined. Varying the HRT between 12 and 20 days had no effect on the fermentation stability and pH remained between 6.8 and 7.6, but an inhibition of methanogenic bacteria was observed at HRT below 12 days. The overall performance of the reactor was depressed by changing the feed concentration from 8% to 10% TS (dry weight). By applying a feed concentration of 6% and HRT of 20 days in the tubular digester, 75% conversion efficiency of FVW into biogas with a methane content of 64% was achieved.

Ojolo et al. (2007) did a comparative study of biogas production from poultry droppings, cattle dung, kitchen waste, fruit waste and vegetable waste (1:3 ratio) under the same operating conditions. 3kg of each waste was mixed with 9kg of water and loaded into the 5 constructed digesters. Biogas production was measured using water displacement method for a period of 40 days and at an average temperature of 30.50C. Results indicated that poultry droppings produced 0.0332dm3/day, cow dung produced 0.0238dm3/day, Kitchen waste produced 0.0080dm3/day, vegetable waste produced 0.0066dm3/day and fruit waste with 0.0022dm3/day of biogas. It was concluded that poultry droppings produced more biogas because it contained more nutrients and nitrogen compared with plant and other animal waste

Ojolo et al. (2007) observed that the amount of solid wastes generated in developing countries such as Nigeria has steadily increased over the last two decades as a result of population explosion and continuous growth of industries and agricultural practices. In agriculture, particularly cattle rearing, large quantities of cow wastes were generated, which could be used as biogas inputs to compliment the fuel usage alternative. In addition, a large number of families generate heavy wastes in the kitchen on a daily basis, which could be converted to economic benefits. In this work, a comparative study of biogas production from poultry droppings, cattle dung, and kitchen wastes was conducted under the same operating conditions. 3kg of each waste was mixed with 9L of water and loaded into the three waste reactors. Biogas production was measured for a period of 40 days and at an average temperature of 30.5oC. Biogas production started on the 7th day, and attained maximum value on the 14th days for reactor 1. Production reached its peak on the 14th day with 85×10-3dm3 of gas produced in reactor 2. For reactor 3, biogas production started on the 8th day and production reached a peak value on the 14th day. The average biogas production from poultry droppings, cow dung and kitchen waste was 0.0318dm3/day, 0.0230dm3/day and 0.0143dm3/day, respectively. It is concluded that the wastes can be managed through conversion into biogas, which is a source of income generation for the society.

Hecht and Griehl (2008) studied laboratory scale anaerobic degradation of kitchen waste, with a high protein and fat content, using a quasi-continuous co-digestion process. The increased accumulation of non-degraded intermediates as an indication of process imbalances was examined in experiments where the substrate load was gradually increased. In addition to the critical rise of known toxic metabolites like ammonia, hydrogen sulphide or volatile fatty acids, aromatic acids accumulated with increasing substrate loading. These metabolites could be identified as intermediates from the anaerobic degradation of the aromatic amino acids phenylalanine, tyrosine and tryptophan. In most experiments the important finding was the early detection of aromatics, especially phenyl acetic acid. Even before the monitoring of volatile fatty acid concentrations gave an indication of a process imbalance. This demonstrated the potential use of aromatic acids as indicators for an upcoming process failure.

Li et al. (2009) studied laboratory scale anaerobic co-digestion of kitchen waste and cattle manure was carried out in batch and semi- continuous modes under mesophilic temperature. Five feed stocks of R1, R2, R3, R4, and R5 were tested, which were made by mixing kitchen waste with cow manure at different mixing ratios of 0:1, 1:1, 2:1, 3:1, and 1:0 respectively. The results showed that 61.0-85.2% of specific methane potential of R2-R4 were contributed by the addition of kitchen waste, which exhibited the highest specific methane potential and biodegradability in batch test. In semi-continuous operation, the methane yield in the digestion of kitchen waste as sole feedstock was 8.8-37.8% less than that of R2-R4. The highest methane yield of 233 ml/g volatile solid was obtained at the mixing ratio of 3:1; therefore, the mixing ratio of 3:1 is recommended as the optimal one for the co-digestion of kitchen waste and cow manure.

II. MATERIALS AND METHODS

A. Treatment of Kitchen Waste

Kitchen waste can be treated using any one of the following methods:-

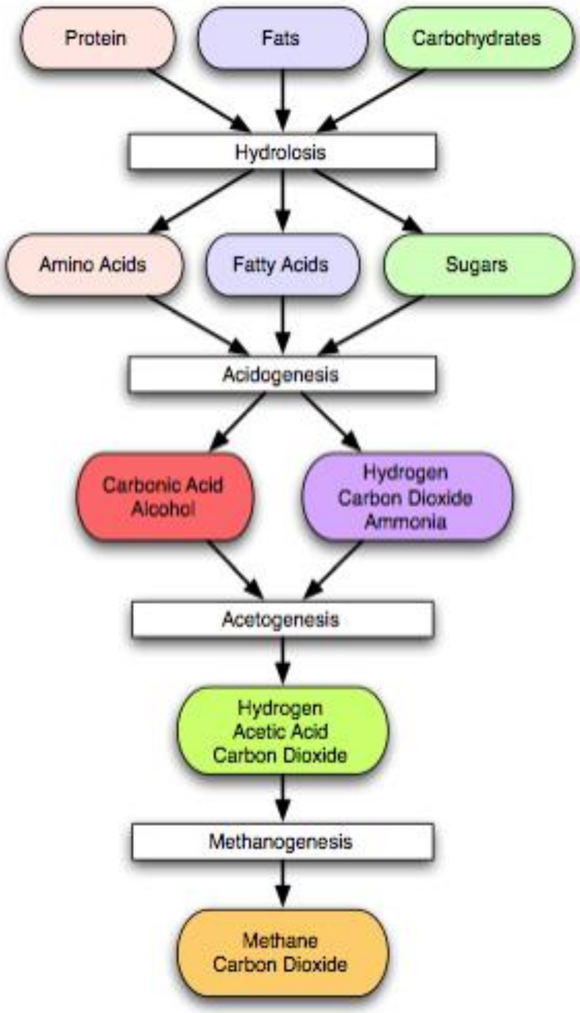
a) Aerobic: It is a bacterial process occurring in the presence of oxygen. Under aerobic conditions, bacteria rapidly consume organic matter and convert it into *carbon dioxide*.
b) Composting: It is a combination of decomposed plant and animal materials and other *organic materials* that are being decomposed largely through *aerobic decomposition* into a rich black *soil*.
c) Land Filling: It is a site for the disposal of *waste* materials by burial and is the oldest form of *waste treatment*. Historically, landfills have been the most common methods of organised *waste disposal* and remain so in many places around the world.
d) Incineration: It is a *waste treatment technology* that involves the *combustion* of organic materials and/or substances.
e) Anaerobic digestion: It is a series of processes in which *microorganisms* breakdown *biodegradable* materia l in the absence of *oxygen*, used for industrial or domestic purposes to manage waste and/or to release energy.

Process and Mechanism of Anaerobic Digestion are:

a) Hydrolysis: It is a chemical reaction during which one or more water molecules are split into hydrogen and hydroxide ions in the process of a chemical mechanism. It is the type of reaction that is used to break down certain polymers, especially those made by step-growth polymerization. Such polymer degradation is usually catalyzed by either acid.

b) Acetogenesis: It is a process through which acetate is produced by anaerobic bacteria from a variety of energy (for example, hydrogen) and carbon (for example, carbon dioxide) sources. The different bacterial species that are capable of acetogenesis are collectively termed.

c) Methanogenesis: It is the formation of methane by microbes known as methanogens. Organisms capable of producing methane have been identified only from the kingdom Archaea, a group phylogenetically distinct from both eukaryotes and bacteria, although many live in close association with anaerobic bacteria. The production of methane is an important and widespread form of microbial metabolism. In most environments, it is the final step in the decomposition of biomass.



B. Materials

1. Cattle Dung: It was procured from Gausala, Ladwa. It was used in the experiments after properly homogenizing it in lab scale grinder in Rudra Institute, Hisar.
2. Kitchen Waste: It was procured from Mastnath Colony, Hisar. Kitchen waste was grinded using a lab scale grinder in Rudra Institute, Hisar.
3. Sludge: The sludge containing active microflora was procured from an already running biogas plant of Gausala, Ladwa.
4. Reactors: The experiments for present study were carried out in batch reactors. These reactors consisted of aspirator bottles of 2 liter capacity. These bottles/reactors were fed with a pre-weighed quantity of homogenously mixed substrate (i.e. slurry of kitchen waste and cattle dung). Anaerobic condition was created in the reactors by sealing their tops using a rubber cork. Through the centre of cork, a hole was drilled & a glass tube was inserted into this hole. Care should be taken to ensure that the end of the glass tube inside the bottle should be well above the level of slurry inside the bottle. The other end of the glass tube would be connected to a silicon rubber tube which would be dipped in a column of water. This arrangement would ensure the exit of gases formed inside the reactor while preventing air from entering into the reactor.

Composition of Kitchen Waste

- Rice
- Onion leaves
- Vegetable left out
- Cauliflower leaves
- Tomato
- Peas
- Chilli
- Tea leaves
- Chapattis

C. Experimental Set up

In all, six different reactors were operated for the present study (Fig). Each reactor except R1 contained 900 ml of solid waste (either KW or CD or combination of two) and 900 ml of water (i.e. in 1:1 ratio) and 200 ml sludge (i.e. seed for starting anaerobic digestion). R1 contained only solid cattle dung without any water. R1 and R2 (1:1, cattle dung: water) were operated as control reactors. Description of all the reactors is given in Table 1.

Table 1: Description of the Experimental Reactors

Reactor	**Description (KW:CD)**
R1	Solid cattle dung alone without any water
R2	0:1
R3	1:0
R4	1:4
R5	1:1
R6	4:1

Gas Measurement: Biogas production was measured using water displacement method.

pH Measurement: pH of all the samples was measured using digital pH meter.

Temperature Measurement: Ambient temperature was measured using glass in mercury thermometer.
Solids: Solids (total and volatile) were analyzed according to the procedures given in "Standard method" (APHA, 1992).

Analysis of Slurry Samples: Initial and final slurry samples were analyzed for pH, total solids and volatile solids for checking the progression of anaerobic process. Initial analysis of samples is given in Table 2

Table 2: Composition of Initial Slurry Samples

Sr. No.	Reactor	Type of mixture (KW:CD)	pH	Total Solids (%)	Volatile Solids (%)
1	R-1	Cattle Dung alone without any water	-	16.65	65
2	R-2	0:1	7.06	8.33	60
3	R-3	1:0	2.89	13.50	75
4	R-4	1:4	6.42	10.00	65
5	R-5	1:1	5.69	8.30	65
6	R-6	4:1	3.81	8.30	65

III. RESULTS AND DISCUSSION

The analysis of final slurry samples is presented in Table 3

Table 3: Composition of Final Slurry Samples

Sr. No.	Reactor	Description (KW:CD)	Ph	Total Solids (%)	Volatile Solids (%)
1	R-1	Cattle Dung alone without any water	-	13.36	1.5
2	R-2	0:1	6.80	1.66	0.33
3	R-3	1:0	-	-	-
4	R-4	1:4	4.30	5.00	1.47
5	R-5	1:1	3.95	5.00	0.10
6	R-6	4:1	3.50	6.67	2.13

pH: The final pH of the samples was found to be 6.8, 4.3, 3.95, 3.5 in reactors R2, R4, R5, R6 respectively. It can be seen from the Table 4.1 that pH of all the reactors operating with kitchen waste was quite low even at the end of the experiment which indicated accumulation of acids due to highly degradable organic matter present in the kitchen waste. However in reactor operating only on cattle dung the pH is in the desired range which showed that there was no accumulation of acids in these reactors and since they were producing good amount of gas till the end of the experiment, this showed that methanogenesis was going on smoothly in these reactors.
Total Solids: It was found that 19.75%, 80%, 50%, 39.75% and 19.63% decrease in total solids was obtained after anaerobic digestion in reactors R1, R2, R4, R5 and R6 respectively. This showed that anaerobic digestion went on smoothly in these reactors. The maximum reduction in total solids was observed in R2 followed by R4. So it can be concluded that in reactor with 0:1 cattle dung (with 1:1 solid: water ratio) total solids reduction was maximum which also produced good quantity of gas.

Volatile Solids: It can be seen from Table 4.1 that negligible amount of volatile solids were left in all the reactors after the end of the experiment .This showed that anaerobic digestion went on smoothly in these reactors. The maximum reduction in volatile solids was observed in R2 followed by R5. It can be concluded that in reactor with 0:1 cattle dung (with 1:1 solid: water ratio) and reactor operated with 50:50 KW and CD nearly same reduction in volatile solids was obtained which can also be correlated with gas production data as shown below.

Production of Biogas: Six different reactors were used for biogas production from which CD alone and CD (1:1) gave good results or produced more biogas as compared to other reactors at regular interval and another reactor R6 (i.e. reactor operated with 100% KW) never produced any gas as its initial sample had very low pH because of which it was never able to regain its performance due to continuous accumulation of acids in the reactor

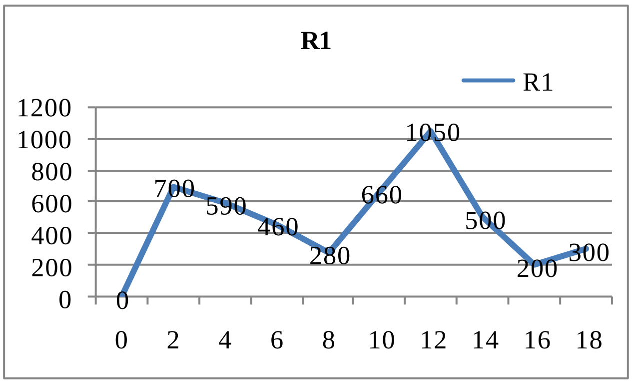


Fig. 1: Biogas production (ml) in R1 (CD alone) reactor

In this reactor solid cattle dung was used for biogas production. This reactor produced good amount of gas at regular intervals. At the 12th day it produced highest amount of gas (1050 ml) as compared to other days as shown in the Fig. 1

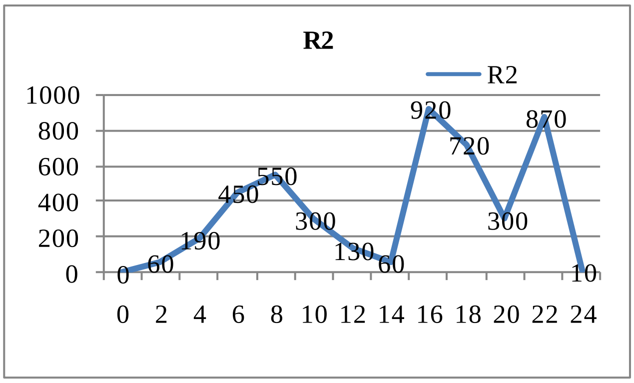


Fig. 2: Biogas production (ml) in R2 (KW: CD) (0:1)

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In this reactor we used (KW: CD) (0:1) for biogas production. It produced highest amount of gas at 16th day (920 ml) as can be seen from the Fig. 2. and at the end of 24th day it stopped producing any gas.

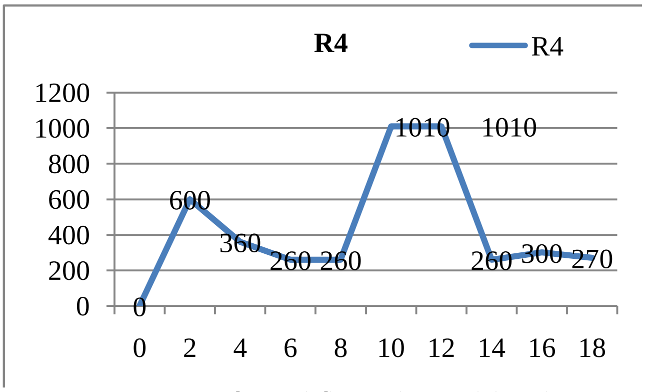

Fig 3: Biogas production (ml) in R4 (KW: CD) (20:80)

In this reactor KW: CD (1:4) was used for biogas production. It produced highest amount of gas from 10th to 12th day (1010 ml) as shown in the Fig. 3

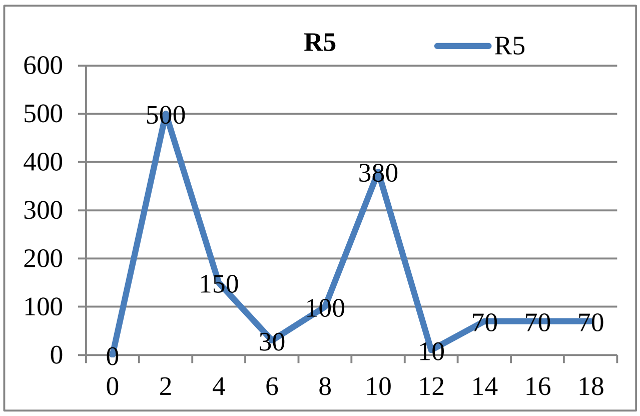

Fig 4: Biogas production in (ml) in R5 (KW: CD) (50:50)

In this reactor KW: CD (1:1) was used for biogas production. It produced highest gas at 2nd day (500 ml) as shown in the Fig. 4

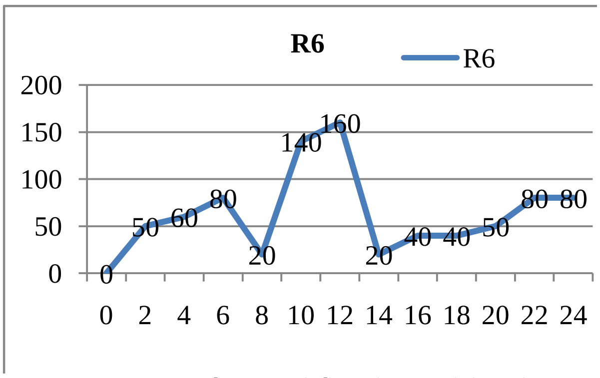

Fig 5: Biogas production in (ml) R6 (KW: CD) (80:20)

In this reactor KW: CD (4:1) was used for biogas production. It produced highest gas at 12th day (160 ml) as shown in the Fig. 5

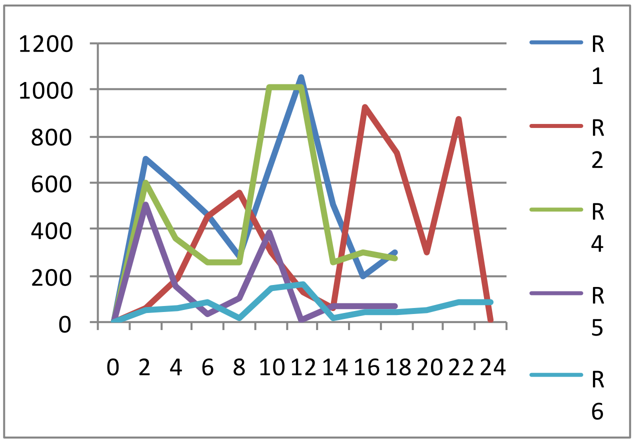

Fig. 6: Biogas production in all the reactors

Out of all these reactors, reactor R1 (solid cattle dung) produced highest amount of gas as compared to other reactors. R1 produced highest amount of gas at 12th day (1050 ml).

Methane Production: After gas analysis for methane production, it was found that 50% methane was produced in CD alone or CD (1:1) and 65 % methane was produced in other reactors (i.e. reactors operated with mixtures of kitchen waste and cattle dung).

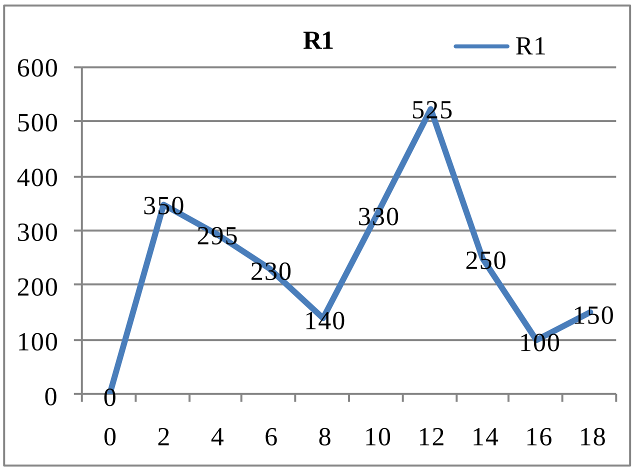

Fig 7: Methane production in R1 reactor

In this reactor solid cattle dung alone was used for methane production. This reactor produced good amount of gas at regular interval. It produced 50% of methane from total biogas production. At the 12th day it produced highest amount of methane (525 ml) as compared to other days as shown in the Fig. 7

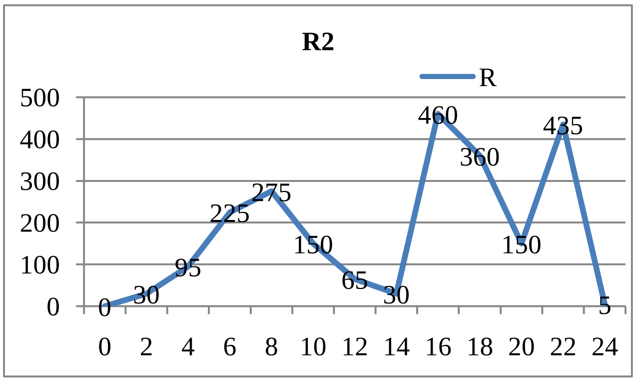

Fig 8: In R2 methane production

In this reactor KW: CD (0:1) was used for methane production. It produced 50% of methane from total biogas production. It produced highest amount of gas at 16th day (460 ml) during its methanogensis process as shown in the Fig.8. And at the end of 24th day it stopped the production of gas.

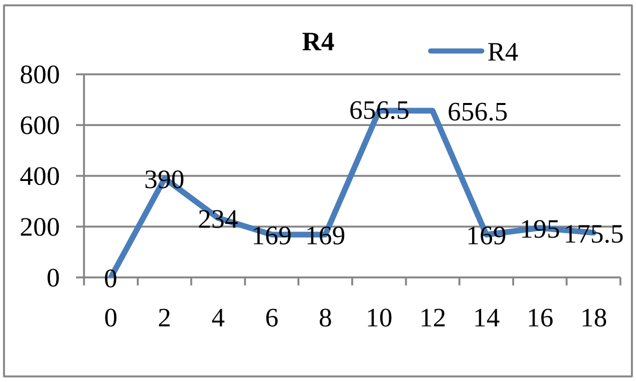

Fig 9: Methane production in R4

In this reactor KW: CD (1:4) was used for methane production. It produced 65% of methane from total biogas production. It produced highest amount of gas from 10th to 12th day (656.5 ml) during its biogas production as shown in the Fig. 9.

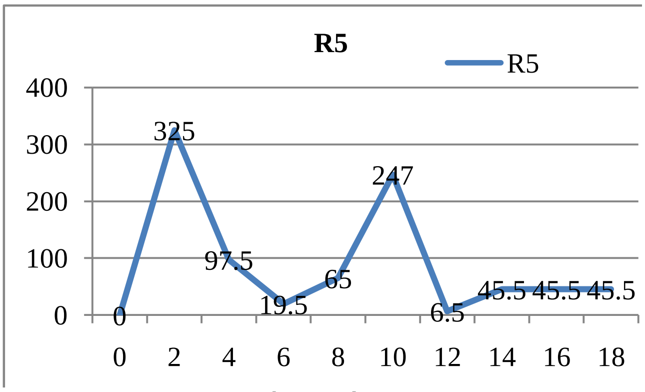

Fig 10: Methane production in R5

In this reactor KW: CD (1:1) was used for methane production. It produced 65% of methane from total biogas production. It produced highest amount of gas at 2nd day (325 ml) as shown in the Fig. 10

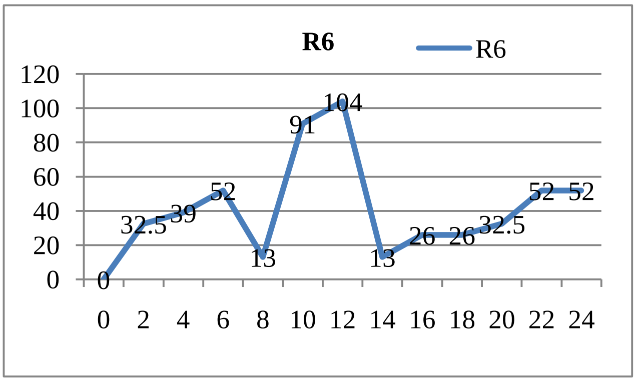

Fig 11: Methane production in R6

In this reactor KW: CD (4:1) was used for methane production. It produced 65% of methane from total biogas production. It produced highest methane gas at 12th day (104 ml) as shown in the Fig. 11

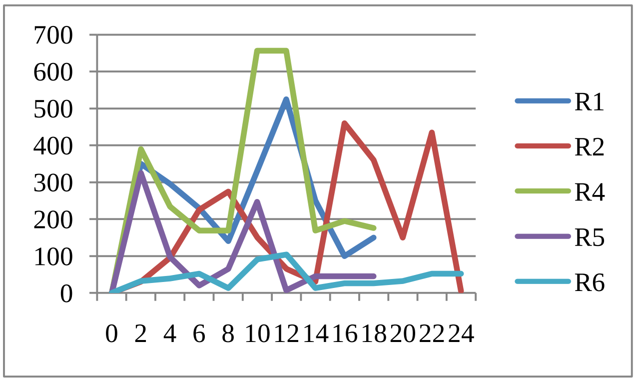

Fig 12: Methane production in all the reactors

It can be seen from the above figure that R1 produced highest amount of methane as compared to other reactors. It was also observed that reactor R2 (KW: CD) (0:1) and R5 (KW: CD) (1: 1) produced nearly same amount of methane and reactor R4 produced highest amount of methane from 10th to 12th day (656.6 ml).

IV. CONCLUSION

Thus, from the present experimental study it was found that the reactor R1 (operated with solid cattle dung alone) produced highest amount of methane and R2 (KW: CD) (0: 1) and R4 (KW: CD) (1: 1) produced the nearly equivalent amounts of methane. So from this it can be concluded that kitchen waste can also be used as a substitute for biogas production in biogas plants operating with cattle dung and water alone in 1: 1 ratio.

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