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BIOGAS PRODUCTION POTENTIAL OF DIFFERENT SUBSTRATE IN VARIOUS COMBINATIONS

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ABSTRACT

Biogas is produced from organic wastes or all types of biological degradable waste by concerned action of various groups of anaerobic bacteria during anaerobic decomposition. Food waste is the best alternative for biogas production in a community level biogas plant.

In the present investigation, an attempt was made to study and compare the rate of biogas production in portable - plastic biogas digester. Different substrates such as cow dung (CD), food waste (FW) and *Jatropha* de oiled cake (JDC) individually and various combinations were tried for the production of biogas. About 5 kg of food waste were collected from the canteen/hostel of PRIST University campus, Vallam, Thanjavur. It was pulverised in a pulveriser and fed into the digester tank along with the cow dung slurry in various concentration and ratios. Likewise *Jatropha* de oiled cake was powered and fed into digester tank alone and in combination with food waste and cow dung. The experiments were carried out for 30 days and the rate of gas production was measured by water displacement method. The pH value of the cow dung, food waste and JDC was nearer to neutral and gradually decreased to acidic and again it got stabilised to the neutral pH which favoured the production of biogas. The percentage of total solids were 97.9, 87.8 and 94.2 for cow dung, *Jatropha* de oiled cake and food waste respectively. The percentage of volatile solids was 73.4**,** 62.2 and 76.3 for cow dung, *Jatropha* de oiled cake and food waste respectively. Observations on daily basis were made on the constituent of biogas, pH, volume and rate of biogas production. Among the 12 different combinations used in the study, maximum production of biogas was achieved in the cow dung and food waste (526 ml) and lowest rate of gas production was achieved in 33.33 % combination of cow dung, *Jatropha* and food waste.

Keywords:

Digester; Slurry; Kitchen Waste; Batch System; Organic Manure

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I.INTRODUCTION

One of the most cost – effective technologies for reducing environmental pollution related to organic waste and food waste is biogas production, which is known to reduce the excessive pollution from the emission of green houses gases (GHG), eutrophication, the spread of diseases and odours [1][2]. Due to the increase in the excessive population there is also simultaneous increase in the rate of food waste production.

Growing energy demand and impacts of fossil fuel contribute towards the commercialisation of biogas as a finite energy source. Organic waste materials are the major attraction for biogas production, through anaerobic digestion that ensures alternative fuel, electricity production, bio fertiliser, waste recycling, green house gas reduction and environmental protection [3][4].

Ordinary waste materials or feed stocks could not provide sufficient biogas production. The accessibility of complex organic materials is a complex task that involve further treatments to ensures absolute degradation and there by biogas production. India has a lot of potential of non-edible oil tree borne seeds [5]. Attempts are being made for using non-edible and under – exploited oils for production of biodiesel [3]. Considering the future scenario of non- edible oil seeds consumption for biodiesel production in the country from *Jatropha* and *Karanja* seeds, there is need for efficient utilization of their cakes. One of the major problems arising in the coming years is disposal of cake after expelling the oil from seed. The cake can be neither used as animal feeding nor directly can be used in agricultural farming due to its toxic nature. The biogas generation from these cakes would be better solution for its efficient utilization of these cakes for energy production and the digested slurry can be directly used for agricultural farming.

Methane is the combustible fraction of biogas, while relatively lower methane content of typical biogas in contrast to conventional energy sources and it is not poisonous. Methane along with other gases occurs naturally in swamps, waste dumps and even in home toilets in the septic tank. Due to its highly flammable quality, it can be

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used as fuel. But capturing the methane from the atmosphere is very complex as it is lighter than air [6] [7]. The Biogas digester or biogas plant is a device which helps us in collecting this gas and it is used as a fuel. During the biogas production microorganisms that thrive in the absence of air digest the organic material by anaerobic digestion and convert the various components of waste into methane, CO_2, hydrogen sulphide, nitrogen and ammonia (i.e. a mixture of gases). Methane is a colourless and odourless gas and is highly flammable. (It is the hydrogen sulphide that smells bad [6][7].

The elemental composition in each organic waste varies with the metabolic processes that take place in its native state. However, carbon/nitrogen ratio of any waste is an adequate measure that desires the rate of microbial degradation of substrate and total methane production. The optimum C/N ratio in the range of 15 – 35 in the feedstock is essential for the higher yield of methane production. The difficult nature of these wastes could be overcome by co-digestion, which could be advantageous due to an improved C/N ratio and dilution of the inhibitory compounds [8][9]. Higher carbon content of animal waste and nitrogen content of agricultural or domestic waste (*Jatropha*/food waste) could influences the characteristics of biogas in larger extent [9]. Therefore, the present study had framed to analyze the biogas production potential in diverse substrates beside with cow dung during co- digestion, in order to investigate the potential substrate mixture for efficient and feasible biogas production in lower HRT. This kind of approach is obligatory for mounting the availability of substrate through out the year to account for large –scale production of biogas in a sustainable manner.

II. MATERIALS AND METHODS

The experiments with lab scale model of digester for biogas production were carried out in small plastic water cans of 5 litres capacity. Different substrate combinations were prepared and the biogas production was studied. The substrates were cow dung, food waste and *Jatropha* de oiled cake.

Sources of Cow dung, food waste and Jatropha de oiled cake

Cow dung was collected from cattle shed of Vallam, Thanjavur. Biodegradable wastes (food waste) were collected from canteen and boy’s hostel of PRIST University, Thanjavur. Food waste includes older mess wastes, rice waste, chapatti, dhalls, vegetables and cooked vegetables. *Jatropha* de oiled cake residues were collected from the oil mill, Madurai. These wastes could efficiently produce biogas in the digester. Chemicals used for processing of food waste and other waste products give hazardous impact to the environment. The process of biogas production from food waste yields high methane production potential than cattle manure & bio solids. So the food waste was being selected as a major source of this study. The experiments were done for 30 days and the rate of gas production was measured by water displacement method.

Equipments and Experimental setup

Equipments used in the study includes, weighing scale of 10 kg capacity, 5 L capacity of water cans used as anaerobic digesters and hand gloves were used to prevent direct contact with the waste respectively. Food waste was brought from boy's hostel and canteen of PRIST University in a plastic container. About 5 kg food waste was collected and stored at 4^{o} C. It was homogenised in a pulveriser and diluted in water and sampled for further analysis.

The plastic cans were subjected to nitrogen flushing for several minutes to remove air and make the system anoxic. The inoculation and filling of the digester were done strictly under aseptic condition. The plastic cans were fitted with screw capped cover and sealed with m- seal after inoculation of the substrates. Then it was connected to the outlet pipe for the collection of gas produced in the digester and it is shown in fig.2. Each digester contained different percentage of cow dung, food waste and *Jatropha* de oiled cake. Twelve different (twelve 5 litre digester plastic cans were used for each of the batch fermentation tests) substrate combinations were prepared and is shown in Table 1. 100 % cow dung acted as the control. Biogas production was monitored throughout the period of the study. During the digestion period, all the samples in the digesters were agitated twice per day to achieve feasible degradation.

The fermentation medium was prepared to ensure sufficient nutrients for bacterial growth and standard pH buffer capacity following the recommendations of VDI 4630 [10] and ISO Standard 11734 (ISO1173, 1995). The following composition was added to the substrate in the digesters in order to enhance the biogas production. The medium includes glucose 10 g; anhydrous potassium dihydrogen phosphate (KH_2PO_4) 0.27 g; ammonium chloride (NH_4Cl) 0.53 g and urea -1 g.

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About 1400 g of cow dung was mixed in 3.5 litres of water, which was recorded as 100 % and 750 g was recorded as 50 %. Likewise the percentage was calculated for all other substrate combinations and was poured into respective container which was allowed for anaerobic digestion processes. The percentage calculations of different substrate are shown in the Table 1.

Table 1. Showing different substrate compositions for biogas production

S. No.	Digester Name	Feed description
1.	D1 (Control)	Cow dung 100 % of 2 Kg = 2 kg
2.	D2	Cow dung (CD) 100 % of 1400 g
3.	D3	*Jatropha* (JD) 100 % of 1400 g
4.	D4	Food waste (FW)100 % of 1400 g
5.	D5	CD + FW (50 + 50 %)
6.	D6	CD + JD (50 + 50 %)
7.	D7	FW + JD (50 + 50 %)
8.	D8	CD + FW + JD (50 + 40 +10 %)
9.	D9	CD + FW + JD (50 + 30 +20 %)
10.	D10	CD + FW + JD (50 + 20 +30 %)
11.	D11	CD + FW + JD (50 + 10 + 40 %)
12.	D12	CD + FW + JD (33.33 + 33.33 +33.33 %)

Analytical Methods and Calculations

The physico- chemical analyses of the substrates were carried out and are shown in Table 2. pH, EC, Salinity, TS, TDS were measured by potentiometeric method. TOC [11] and TKN were determined according to standard procedures [12]. Total solids (TS), Volatile solids (VS) and volatile fatty acids (VFA) was determined according to method of [13].

Total solids (TS %) – It is amount of solid present in the sample after the complete evapourisation of water present in it. Approximately 10 gm of the sample was taken, poured in foil plate and dried to a constant weight at about 105° C in muffle furnace.

TS % = (Final weight / Initial weight) * -------------------- (i)

Volatile solids (VS %) – Dried residue from total solids analysis weighed and heated in crucible for 2 hrs at 500 º C in muffle furnace. After cooling, the crucible residue was weighed.

VS % = [100 – V3 – V1 / (V2 – V1)] * 100 ----------------- (ii)

V1 = Weight of crucible

V2 = Weight of dry residue and crucible.

V3 = Weight of ash and crucible (after cooling)

Volatile Fatty Acid (VFA) – Volatile fatty acids (VFA's) are fatty acids with carbon chain of six carbon or fewer. They can be created through fermentation in the intestine. It includes: acetate, propionate and butyrate. It was measured by titration method. 100 ml of sample was taken in a beaker. Then it was filtered and pH was checked. 20 ml of filtrate was taken and 0.1 M HCl was added until pH was reaches 4. It was then heated in a hotplate for 3 minutes. After cooling it was titrated with 0.01 M NaOH to reach the pH of 7. The amount of HCl and NaOH consumed was recorded.

Total VFA content in mg/l acetic acid = (Volume of NaOH titrated) * 87.5 --------- (iii)

Table 2 Showing the parameters and methods for examination of different substrates (cow dung, food waste and *Jatropha* de oiled cake and their digested slurries).

S. No	Parameters	Method
1.	pH	Potentiometer
2.	EC	Electrical Conductivity meter
3.	Salinity	Potentiometric method
4.	TS	Gravimetric method
5.	TDS	Potentiometric method
6.	Nitrogen	Microkjedhal
7.	TOC	Walkey and Black, 1986
8.	VS	Gravimetric method
9.	VFA	Titration method
10.	Methane	Syringe method and water replacement method.

Methods to measure volume of biogas produced

The measurements of biogas produced were carried out using two techniques such as syringe method and liquid replacement system continuously connected to the reactors (CLRS). The gas yield was measured daily during the first week of incubation, every 2 day during the incubation period. The incubation period was stopped when the gas production rate was less than 1 % of the accumulated gas produced.

Continuous measurements with liquid replacement system (CLRS)

Biogas volume was measured using a CLRS, which was permanently connected to the reactors for the entire experimental period.

Intermittent measurements with syringe

The volume of biogas was measured using a 50 ml syringe supplied with a tube with a needle at the open end. The syringe was connected to the reactors by injecting the needle through the butyl bung, the drawing the plunger out until the pressure in the head space dropped to ambient pressure. The volume of gas in the syringe was taken as a measurement of the gas produced.

Wet Chemistry CH_4 measuring method

The concentrations of CH_4 in biogas was frequently measured by absorbing CO_2 in an alkaline liquid [14][15][16]. A cylindrical flask was filled with liquid and placed with the opening in the same liquid in a container (Fig.2), so that the flask rains full of liquid. To the inside of the cylindrical flask was attached a tube closed with a clamp and with a syringe at the other end. The syringe was injected through the butyl bung of the reactor, the clamp was opened, and the gas produced flows into the cylindrical flask and replaces the liquid. The amount of liquid replaced corresponds to the volume of gas produced. If the liquid was acid, the volume of biogas produced was measured, while if the liquid was basic, the CH_4 production was measured.

In the test, 1 litre graduated measuring cylinder and 1 litre container were used, as described above. About 700 ml of 0.5 M hydrochloric acid (HCl) were used to fill the cylinder and added to the container. On injecting the needle into the plug of a reactor, biogas bubbles through the liquid and fills the cylinder, replacing the liquid, and the gas volume can then be read (V1- ml). Therefore, KOH was added to increase pH to above 9 to absorb H_2S and CO_2. This absorption reduces the volume of gas in the measuring cylinder (V2- ml). The volume V2 was an estimate of CH_4 in the gas; the difference between initial and final volume corresponds to the CO_2 content in the biogas, i.e. H_2S concentration was taken as negligible compared with CO_2 concentration.

Hydraulic Retention period

The optimal period for the economical gas production in batch fermentation depends largely on pattern of daily gas production and the pattern of changes in the calorific value of gas produced i.e. CH_4 content. The study period in the experiment was 30 days.

III. RESULTS AND DISCUSSION

The results of the analysis of physicochemical parameters of the fresh substrates and the digested slurries are shown Table 3 and 4. pH, EC, salinity, TDS, TOC, TKN of the substrate before digestion and after digestion are given in the Table 2 and 3. The pH ranged from 5.89 to 6.94 for the different substrates used for the study. The pH was adjusted to neutral (7.0 to 7.2) by adding NaOH to enhance and accelerate the production of biogas in the digester. Total solids (%), Volatile solids (%) and Volatile fatty acid (VFA) content of the different substrate in the corresponding batch digester, fresh substrates (before feeding) and slurries (after digestion) were analysed and shown in Table 3 and 4.

The common environmental parameters showed variation on time during anaerobic digestion. The higher pH of 8.1 and lower pH of 6.6 was observed at 30th day in D3 and D12.

The initial pH of cow dung, food waste and *Jatropha* de oiled cake was 6.2, 6.29 and 5.6 respectively and then it was adjusted to 7 with NaOH at the start up period. pH of the system gradually increased to a final pH of 8.1 in the reactor systems (*Jatropha*) and remained at a pH of approximately 7.4 (food waste). The increase in the pH was due to the release of ammonia by methanogens during methanogenesis [9][17]. However, the increase of pH up to 8.5 is recognized as favourable pH range, while highly basic pH may cause process unsteadiness due to accumulation of ammonia [18]. Similarly, lower pH (< 5.0) would drastically affect methanogenesis by the accumulation of volatile fatty acids. Hence the final pH range of 6.5 – 8.1 showed stable biogas production, in the present study.

In the present study co-digestion of selected substrates along with cow dung was established to accomplish optimum C/N balance ratio for enhancing biogas production [19]. It also revealed the maximum solid removal has been accomplished by co-digestion of organic materials with cow dung.

The biochemical composition of the substrates mixture during the digestion period showed that there was a gradual decrease in biochemical characteristics such as total solids, volatile solids and VFA from the 0^{th} to 30^{th} day. However the organic nitrogen content was subsequently increased during the digestion process. Considerable solid removal has been achieved in all the substrates mixtures, which was supported by the reduced rate of total organic carbon (Table 3 & 4). The present study revealed that the system with low solid content of **9 %** was found to be satisfactory for biogas production. Likewise, the higher solid removal was obtained in this study due to the maintenance of sufficient total solid and volatile solid content through co-digestion. These results are supported by the earlier experiments that showed a total solid content of about 7- 8 % was significant for a considerable rise in biogas production than high solid content [20].

Quantitative Analysis of Biogas yield

Cumulative yields of biogas (expressed in ml) from cow dung, food waste, *Jatropha* de oiled cake and admixtures with cow dung and the trend in the production of

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biogas are shown in Table 5. The gas production of various treatments at different hydraulic retention time is presented in fig. 2

The production of gas in the bioreactor started after 5 days of operation. The rate of production increased gradually during 12 - 16 days, then sharply increased after 20 days of digestion and reached to a peak in 22 to 26 days (fig.3). [21] studied a batch culture anaerobic digestion of banana stem waste under mesophilic conditions at 37º C and compared the CH_4 production from different solid content. They found that the conditions of 2 – 4 % total solids (TS) achieved higher CH_4 yield than the higher solid content of 16 % TS.

The maximum gas production was in D5 which was found to be 485 ml at 24 days HRT. However, gas production of 24 days HRT in the treatments D1,D2, D3, D4, D6, D7, D8, D9, D10, D11 and D12 were 362, 186, 365, 485, 230, 223, 456, 398 and 387 respectively (ml /kg weight of waste). The ambient temperature during the period of experimentation was in the range of 30 to 37º C during January to February 2016.

The rate of biogas production from FW was observed to be rapid when compared to cow dung during the second week of fermentation. With the growth of fermentation, the rate of production in the mixtures of CD+ FW+ JD (D8) increased substantially and biogas yield was faster in food waste along with cow dung than that from treatment with cow dung alone. JD and FW alone produced biogas of 365 and 186 ml in 24 days and thereafter its production attained steady pace. The trend pointed out a gradual increase to a maximum between 15 to 24 days and then the gas production is maintained at a high level to the end of the experiment [22]. The total period taken for digestion was 30 days, beyond which the gas yield were more or less stopped as observed for all the treatment CD:JW: FW.

‘’Reference [23] studied the biogas production from *Jatropha curcas* seed cake enriched with digested cattle dung and operated in semi continuous system, the methane yield obtained from 10 % of total solids (TS) of *Jatropha curcas* seed cake (biogas production of 333 L/kg seed cake) was higher than that obtained from 15 % of total

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solids (biogas production of 287 L/kg seed cake)''. The results of the present study also well correlated with this finding.

But the CD:FW treatment in the 1:1 ratio showed a steady increase in biogas generation through out the period of study and yielded the highest amount of biogas i.e. 496 ml/kg dm followed by FW and CD+ FW+ JD generating 485 and 456 ml/kg dm respectively. Most of the treatments have shown biogas potential higher compared to cow dung. This higher yield may be due to the synergistic action of micro organisms from co-digestion process. This type of higher yield was observed by many researchers [24][25] using different substrates as feedstock. The weekly gas yield records revealed that for the production of about 70 percent of the total gas, treatment with cattle dung alone had taken around 35 days [26]. In the present study the gas production results suggested that the food waste alone has 90 percent biogas production potential to conventional cow dung. This also recorded a faster rate of high amount of gas production at a shorter retention period of 15 to 18 days than that of other combinations of substrates which had taken a longer retention time of 35 days [27].

It was observed that the biogas production from CD+ FW+ JD was continued for a period of 35 days but at a lower rate. The yield of biogas obtained during the study period amounted to about more than 80 percent of the total gas. The supplemented treatments had taken more time than cow dung alone for complete biodegradation due to its difference in its physicochemical characteristics due to various proportions of cow dung, food waste and *Jatropha* de oiled cake [28].

The biogas yield results indicated that the processes of biogas generation from a mixture of animal waste with carbonaceous substrate proceeds better than that of animal waste alone and this is in agreement with that reported by [29, 30, 31] as biogas production from swine manure supplemented with corn stalks was enhanced in excess of 50 % than non supplemented manure.

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IV. CONCLUSION

The quantitative analysis of biogas production from 12 different substrates mixtures showed that the water displacement has been gradually increased from 0th to 30th day, which indicated the production of biogas in respective bio digester. There was maximum total solid and volatile solid removal in all of different substrate combinations through co-digestion. The increased pH of 30th day revealed that appropriate degradation occurred throughout the process. The maximum biogas production was achieved in food waste and cow dung (1:1) mixture in contrast to the other combination of *Jatropha* and cow dung. This study concluded that the food waste + cow dung is the potential substrate mixture which could be effectively used for biogas production, which offers further advancements in biogas production technology through co-digestion in course to commercialise biogas in future.

Table 3. Physicochemical parameters of fresh substrates

S.No	Name of waste	pH	EC	Salinity	TS %	TDS	VS %	VFA (mg/l)	Nitrogen (%)	TOC %	C/N ratio
1	Control	6.94	4.11	3.81	53.3	3.98	71.2	285	2.3	49.6	21.57
2	Cow dung (CD)	6.2	4.2	3.37	56.2	4.89	73.4	263	2.2	48.7	22.14
3	*Jatropha* De oiled cake (JD)	6.29	13.2	3.45	87.8	7.25	62.2	296	3.8	46.3	12.18
4	Food waste (FW)	5.6	12.9	11.5	94.3	7.19	82.3	345	1.2	36.6	30.50
5	CD + FW (50 + 50 %)	6.3	5.62	5.43	92.3	3.15	78.6	298	2.1	48.9	23.29
6	CD + JD (50 + 50 %)	6.6	6.68	5.89	91.8	3.65	73.2	310	2.2	37.6	17.09
7	FW + JD (50 + 50 %)	5.89	7.66	6.99	94.6	4.27	79.3	345	2.9	43.6	15.03
8	CD + FW + JD (50 + 40 + 10 %)	6.14	5.34	84.8	83.2	3.05	62.3	336	2.1	33.8	16.10
9	CD + FW + JD (50 + 30 + 20 %)	6.34	5.96	5.48	85.3	3.37	61.8	321	2.4	35.9	14.96
10	CD + FW + JD (50 + 20 + 30 %)	6.21	6.1	5.7	89.6	3.44	69.6	348	2.6	37.8	14.54
11	CD + FW + JD (50 + 10 + 40 %)	6.3	6.63	6.17	87.5	3.72	67.8	364	2.7	38.9	14.41
12	CD + FW + JD (33.33 + 33.33 + 33.33 %)	5.89	3.81	3.46	84.4	2.1	68.3	372	2.1	24.6	11.71

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Table 4. Physicochemical parameters of digested substrates

S.No	Name of waste	pH	EC	Salinity	TS %	TDS	VS %	VFA (mg/l)	Nitrogen (%)	TOC %	C/N ratio
1	Control	6.9	3.88	2.56	16.7	2.89	9.8	327	2.6	43.3	16.65
2	Cow dung (CD)	6.8	3.69	2.87	16.45	3.32	9.6	346	2.3	44.6	19.39
3	*Jatropha* De oiled cake (JD)	8.1	11.9	3.12	28.4	6.98	16.4	420	3.9	42.7	10.95
4	Food waste (FW)	7.2	8.6	8.92	18.4	5.95	9.2	389	1.6	31.8	19.88
5	CD + FW (50 + 50 %)	7.1	4.32	5.23	16.56	2.55	8.5	346	2.5	43.6	17.44
6	CD + JD (50 + 50 %)	6.6	6.89	5.45	18.9	2.98	7.6	412	3.2	35.7	11.16
7	FW + JD (50 + 50 %)	7.5	4.32	5.36	21.6	4.13	12.3	436	2.6	40.9	15.73
8	CD + FW + JD (50 + 40 +10 %)	6.8	4.78	6.43	20.5	2.67	11.7	435	2.8	30.9	11.04
9	CD + FW + JD (50 + 30 +20 %)	6.7	5.96	4.56	19.6	2.98	10.4	428	2.9	31.6	10.90
10	CD + FW + JD (50 + 20 +30 %)	6.3	5.98	4.79	23.8	2.36	13.9	456	3.1	32.5	10.48
11	CD + FW + JD (50 + 10 + 40 %)	6.5	6.76	5.2	28.6	2.57	14.2	475	3.4	32.6	9.59
12	CD + FW + JD (33.33 + 33.33 + 33.33 %)	6.6	3.56	5.67	29.5	2	16.7	489	2.9	21.6	7.45

Table 5. Rate of biogas production vs Number of days in various substrates

S. No	Name of waste	4	6	8	10	12	14	16	18	20	22	24	26	28	30
1	**Control**	38	34	30	74	152	167	184	221	258	316	362	356	322	312
2	**Cow dung (CD)**	40	36	31	85	160	173	189	225	260	320	365	345	332	321
3	***Jatropha* de oiled cake (JD)**	15	16	25	27	29	37	89	98	148	154	186	182	176	167
4	**Food waste (FW)**	33	30	26	48	140	210	235	285	325	435	485	482	476	456
5	**CD + FW (50 + 50 %)**	48	28	26	52	156	236	284	325	390	448	496	489	477	463
6	**CD + JD (50 + 50 %)**	28	34	22	47	78	110	132	148	165	205	230	225	221	218
7	**FW+ JD (50 + 50 %)**	27	31	23	41	73	98	127	139	159	210	223	216	210	202
8	**CD + FW + JD (50 + 40 + 10 %)**	45	24	22	48	149	223	278	315	375	434	456	442	436	431
9	**CD + FW + JD (50 + 30 + 20 %)**	42	21	18	43	138	216	266	297	349	376	398	378	364	353
10	**CD + FW + JD (50 + 20 + 30 %)**	38	18	14	38	125	212	258	286	338	353	387	376	368	361
11	**CD + FW + JD (50 + 10 + 40 %)**	30	15	12	32	110	205	249	254	310	342	360	358	349	337
12	**CD + FW + JD (33.33 + 33. 33 + 33.33 %)**	10	7	5	8	13	20	39	47	56	59	65	63	56	48

Fig. 1. Showing the experimental setup - A. Control, Cow dung (100 %), CD + JD + FW (33.33 % + 33.33 % + 33.33 %), B. *Jatropha* (100 %), Food waste (100 %), CD + JD (50 + 50 %), C. CD + FW (50 + 50 %), JD + FW (50 + 50 %), CD + JD + FW (50 + 40 + 10 %), D. CD + JD + FW (50 + 20 + 30 %) CD + JD + FW (50 + 30 + 20 %) CD + JD + FW (50 + 10 + 40 %)

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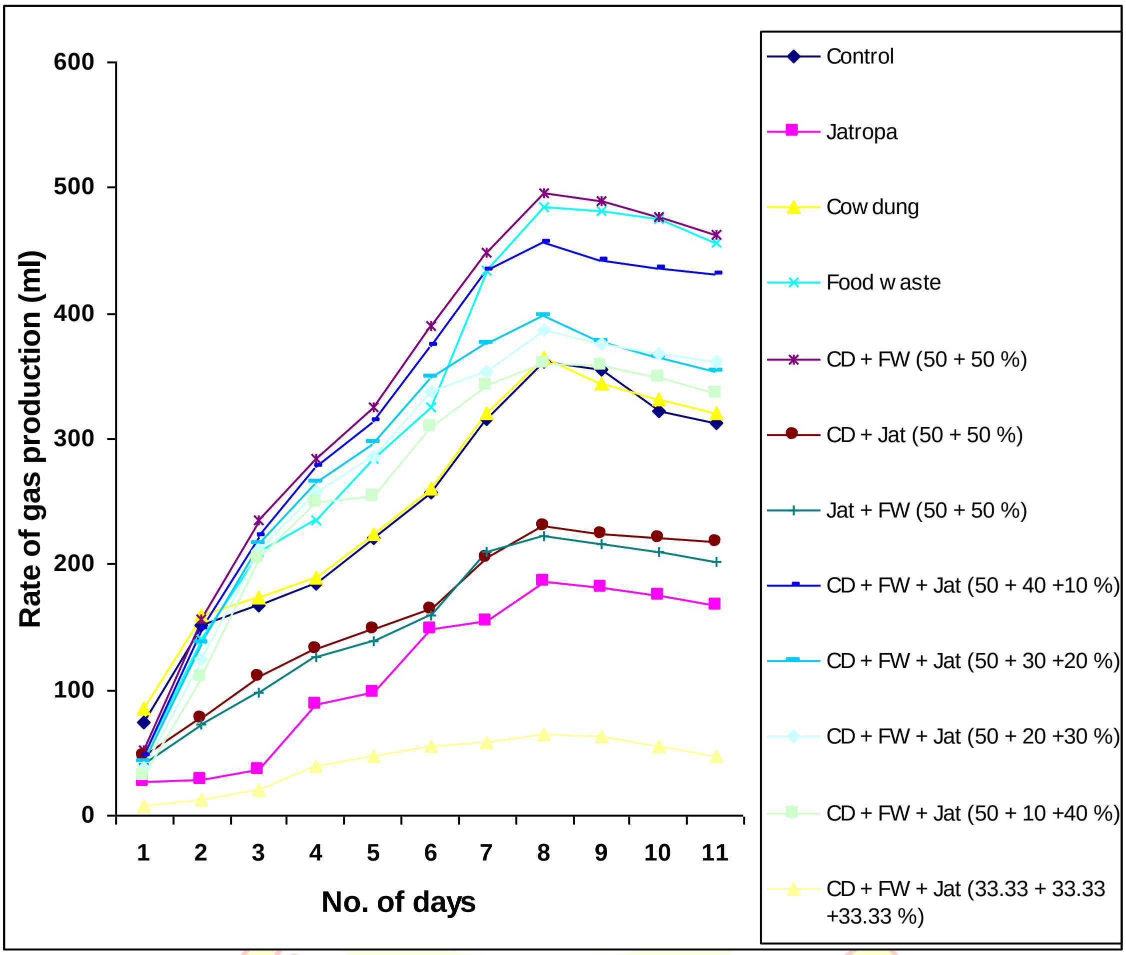

Fig. 2. Daily production of biogas yield with different substrates combinations

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