Kumari *J Pure Appl Microbiol,* **13**(**4**), 2507-2515 | December 2019
Article 5965 | https://doi.org/10.22207/JPAM.13.4.66
Print ISSN: 0973-7510; E-ISSN: 2581-690X

RESEARCH ARTICLE OPEN ACCESS

Bioremediation and Bioprospecting of Cow Dung and Poultry Droppings Enriched with Sewage Water for Biogas Production

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Abstract

In this study, the biogas was produced by the gradual replacement of cow dung using sewage water and poultry dropping. Cow dung replacement with sewage water showed high utility of the total solids than the control bioreactor. In control bioreactor the total solid reduction is ranged between 10% and 9.8%, whereas in the experimental bioreactor which contained the gradual replacement of cow dung with sewage water, the total solid degradation occurred from 10% to 6.1%. The analysis of biogas production by gradual replacement of cow dung with poultry droppings and sewage water revealed the total solids degradation range from 7.2% to 6.7%. Total solid level reduction is considered to be one of the important parameter for biogas production. Regarding the production of biogas, the gradual replacement of cow dung with sewage water experimental reactor gave more biogas (1421lit/kg of dry matter/day) when compare to the control bioreactor (1007lit/k g of dry matter/day). The maximum gas production also occurred at 80% replacement with sewage water. The gradual replacement of cow dung with poultry droppings supplemented with sewage water revealed the high gas production (1952lit/kg of dry matter/day) than the cow dung replacement with sewage water and control bioreactors. During the gradual replacement of cow dung with poultry droppings and sewage water concluded that there is an excellent biogas production in the 100%replacement of cow dung which in turn indicated that poultry droppings contains more total solid level which can be easily degraded by methanogenic organisms than in cow dung and sewage water can be a good nutrient source for biogas production.

Keywords: Total solid level, biogas production, methanogenic organisms, sewage water.

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(Received: 22 November 2019; accepted: 24 December 2019)

Citation: V. Jeyanthi Kumari, Bioremediation and Bioprospecting of Cow Dung and Poultry Droppings Enriched with Sewage Water for Biogas Production, *J Pure Appl Microbiol*., 2019; **13**(**4**):2507-2515. https://doi.org/10.22207/JPAM.13.4.66

INTRODUCTION

Agro-industrial residues, sewage water, large poultry and pig farms are often a major source of pollution in Asian countries[1]. The production, distribution, use, misuse, disposal of sewage water have polluted the environment that threatens the health of humans, livestock, wildlife and indeed whole ecosystems. At the same time these pollutants constitute a large potential for biogas production through anaerobic digestion[2]. The government, industry and the public have needed the effective alternatives to traditional physical and chemical methods for sewage management[3].

In India, the biogas technology is based on cattle dung as the main feed stock[4]. Biogas has been produced traditionally from cattle dung but the reports about the need of cattle dung has been increased in years because of the reduced number of cattle[5]. The alternate substrates like excreta of sheep, goat, pig and other animal wastes both in combination with cattle dung and alone are possible to produce biogas[6,7].

The raising cost and shortage of conventional fuel have generated renewed interest in producing methane from organic matter through anaerobic digestion[8]. The production of energy from alternative sources becomes not only more desirable but economically more feasible[9,10]. Biogas is one of the promising sources of alternative energy and the biogas technology of modern plant produces clean renewable with nutrient rich digested slurry[11].

Technologies for treating farm wastes along with sewage polluted environments have been a major concern over the last couple of decades[12]. Research on anaerobic degradation of cellulosic wastes of cattle dung for enhanced biogas and ethanol production has shown the degrading ability of rumen microorganisms in biogas production[13,14]. The successive biogas production occurred when poultry droppings, parthenium and eucalyptus leaves with donkey dung combination[15].

The temperature has a significant influence on methanogenic bacterial activity, bioremediation and stabilization efficiency in biogas production[16]. The effect of temperature is independent of loading rate and retention time[17]. The methanogenic activity, anaerobic biodegradability and toxicity are key parameters in the design and operation of anaerobic bioreactor[18,19]. There was no significant inhibition of biogas production in the presence of salinity but this salinity along with ammonium nitrogen levels have an impact on biogas production[20].

Chemical oxygen demand, dry solids, volatile fatty acids and reactor volume occupied by the feed material are the important parameters in the biogas production. Effective bio conversion of organic matter in anaerobic digester depends on a diverse microbial population[21]. The slurry from biogas plant after biogas production used as a nutrient source in agriculture[22]. The bio digested slurries of biogas plant used as carriers for the preparation of carrier based inoculums acclaimed to play a vital role in modern agriculture[23,24]. In this study, the sewage water which is consider to be the chief source of contamination used as supplementary feed and replacement source along with cow dung and poultry droppings for biogas production.

MATERIALS AND METHODS

Sample Collection

The present work was carried out using sewage water of Sewage effluent Treatment Plant (STP) of A.P.C. Mahalaxmi College campus, Thoothukudi. This is used as supplement for the production of biogas. The sewage water for STP is directly collected from hostel septic tanks, old hostel, new hostel and mess.

Characteristics of sewage water

The following parameters were analyzed in sewage water both in control and experimental bioreactors. The Total Solids (TS), Volatile Fatty Acids (VFA) and Total Volatile Solids (TVS) were estimated as per the procedure given in MACs manual (1988)[25].

Bioreactor and loading Mode

In this experiment KVIC (Kadhi Village Industries Commission) model anaerobic bioreactors were used for biomethanation process. Semi continuous process was followed for biogas production. Anaerobic bioreactors were used. The total capacity of a bioreactor is 46 liters. Cow dung and poultry droppings were used as substrates. For experimental purpose these substrates were supplemented with sewage water and the biogas production was done in a separate manner. The digesters were daily charged by these substrates for their stabilization. The experiment was carried out for the period of nearly 250 days continuously.

(i) In the first part of work, the control bioreactor was loaded with cow dung and ordinary water and the experimental bioreactor was loaded with cow dung supplemented with sewage water. The Retention Period (RT) for30days was maintained. After 30days the gas output was measured by water replacement method[26].

(ii) In the second part of work, the cow dung amount was gradually reduced by sewage water in the order of 20%, 40%, 60%, 80% and 100%. Total Solid (TS) concentration was maintained at 10% level. The gas output was measured by water replacement method.

(iii) Another set of experiment setup was carried out in the above said same manner but the cow dung was replaced in the order of 20%, 40%, 60%, 80% and 100% level by poultry droppings with sewage water in the interval of 15 days. The sewage water level was maintained constantly. Here also the gas output was measured by water replacement method.

Table 1. Characteristic features of sewage water

TS(%)	TVS(%)	N(%)	P(%)	K(%)	C(%)
9.360±3.207	60.290±2.472	1.12±2.039	0.32±1.074	0.28±1.937	28.2±3.008

Table 2. Total Solids (TS), Total Volatile Solids (TVS) and Volatile Fatty Acids (VFA) in control bioreactor

No of	TS(%)		TVS(%)		VFA(%)
days	Initial	Every 15 days interval	Initial	Every 15 days interval	
0day	10.0 ±2.516	7.6 ± 1.835	60.1±0.311	62.2 ±1.997	42.0 ±0.057
15th day	10.0 ±1.732	7.9 ± 1.646	60.3±0.352	64.2 ± 0.900	44.0 ± 0.132
30th day	9.8 ±1.250	7.6 ±2.657	61.7±0.702	66.2 ± 0.950	40.0 ± 0.374
45th day	9.4 ±1.692	7.6 ±1.662	60.7±0.680	64.8 ± 1.193	43.0 ±0.497
60th day	9.6±1.587	7.8 ± 1.743	59.5±0.789	62.4 ± 0.680	40.0 ±1.647
75th day	9.4±2.285	6.6 ± 0.208	60.3±1.200	63.8 ± 2.066	40.0 ± 0.923
90th day	9.8±0.513	6.4 ±0.351	61.4±0.808	64.2 ±1.153	42.0 ± 0.947

Values in Mean ± Standard Deviation.

Table 3. Total Solids (TS),Total Volatile Solids(TVS) and Volatile Fatty Acids(VFA) in Experimental bioreactor(cow dung replacement with sewage water)

No of days	Amount of cow dung replacement with sewage water	TS (%)		TVS (%)		VFA (%)
		Initial	Every 15 days interval	Initial	Every 15 days interval	
0day	0%	10.0±0.100	6.3±1.053	57.4±0.585	65.8±1.504	52.0±1.230
15th day	20%	9.8±0.305	6.6±0.608	58.9±1.792	66.2±1.150	50.0±0.870
30th day	40%	9.4±0.493	6.9±0.550	57.3±0.642	66.8±2.954	58.0±0.043
45th day	60%	9.0±0.110	6.1±0.150	56.9±2.668	64.9±1.616	48.0±0.032
60th day	80%	8.8±0.152	6.8±0.519	61.9±2.193	72.8±1.101	48.0±0.743
75th day	100%	8.4±0.757	7.2±1.106	59.6±1.817	68.2±5.466	46.0±1.687
90th day	100%	8.1±1.156	7.1±0.251	59.5±2.569	68.8±6.086	52.0±1.1043

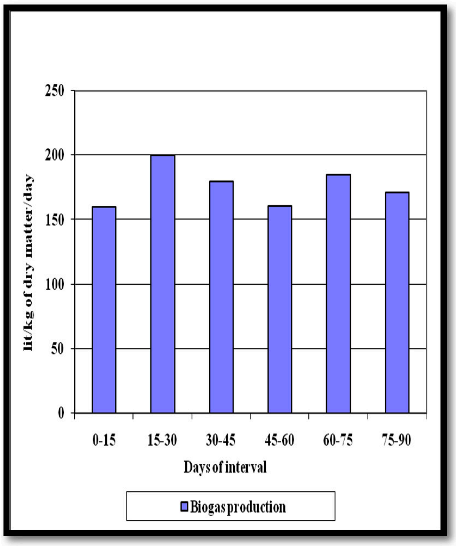
Values in Mean ± Standard Deviation.

Characteristics of outlet slurry

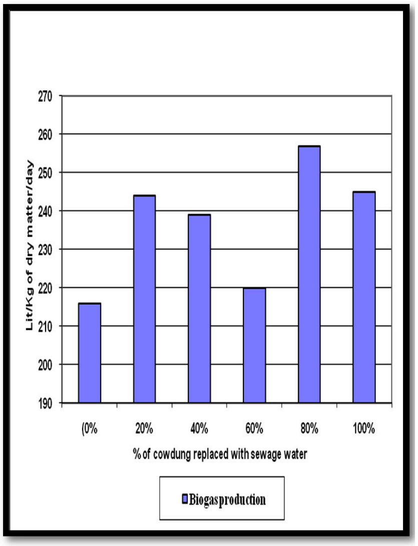
The parameter analyses of outlet slurry were also done. The important parameters, pH and temperature were analyzed routinely both in control and experimental bioreactor. The temperature was ranged between 36°C to 38°C throughout the experimental period.

Statistical analysis

The characteristic feature of sewage water (Table 1), Total solids (TS), Total Volatile Solids (TVS) and Volatile Fatty Acids (VFA) in control bioreactor (Table 2) and experimental bioreactor of cow dung replaced with sewage water (Table 3) and all the experimental data were calculated by the average (mean) and standard deviation and given in the table as mean±SD by using Microsoft Excel. Then the values were tested by ANOVA (analysis of variance) which revealed that there is a significant difference between the control and experimental bioreactor in gradual replacement of cow dung with sewage water (Table 4). The Student's 't' test to explain the impact and individual analysis of TS, TVS & VFA for the biogas production in the case of gradual cow dung replacement with sewage water (Table 5). The observed values of temperature and pH of both control and experimental bioreactors



X_c =44.94
σ_c=25.23
C.V$_c$= $\frac{\sigma_c}{X_c}$x100=56.14



X_c =45.87
σ_c=25.54
C.V$_c$= $\frac{\sigma_c}{X_c}$x100=55.67

Fig. 1. Biogas production in control and experimental bioreactor (cow dung replaced wit sewage water)

Table 4. Analysis of varience (ANOVA) for the production of biogas between control and experimental bioreactor

Sources of Variation	Degrees of freedom	Sum of squares(x)	sum of squares(y)	Mean sum of squares(x)	Mean sum of squares(y)	Table value of F
Between Means	2	17016.28	19269.21	8508.14	9634.61	3.55
Between products	18	13.55	42.96	0.75	2.39	
Total	20					

Calculated value of F for x and y are greater than that of the table value of F for(2, 18) degrees of freedom. There is a significant difference between the control and the experiment. Based on that the further analysis was worked out for the same separately by using student 's t-test.

which included the gradual replacement of cow dung with sewage water and gradual replacement of cow dung with poultry droppings and sewage water (Table 6) were recorded. Analysis of variance (ANOVA) for the production of biogas between control and experimental bioreactor of cow dung replacement with poultry droppings and sewage water is incorporated in Table 7. In Table 8, Student's "t" test analysis of TS, TVS&VFA for biogas production by gradual reduction of cow dung supplemented with poultry droppings with sewage water was recorded and it revealed that they have very significant effect on producing TS, TVS and VFA. The Coefficient of variance analysis report revealed that experimental bioreactor is producing consistent biogas in the both experimental trials.

RESULTS

The study on the replacement of cow dung with sewage water showed high utility of the total solids from its initial level than the control bioreactor (Table 2 & 3). In the experimental bioreactor the total solid degradation occurred from 10% to 6.1%. From this it was observed that there was a significant gradual solid reduction in experimental bioreactor when compared to control.

The analysis of biogas production by gradual replacement of cow dung with poultry droppings and sewage water revealed that the total solids ranged between 7.2% and 6.7%. This indicated that there was a significant solid reduction in experimental bioreactor when compare to control. The utility of solids by microbes in turn indicated the high productivity of biogas. Also high utility of total volatile solids, volatile fatty acids were observed in both experimental bioreactors compared to the control bioreactor respectively. Throughout the experimental period the pH ranged between 7.0 and 7.3. The temperature changes both in control and experimental bioreactors were observed between 36°C and 38°C respectively (Table 6).

The results revealed that the cow dung replaced with sewage water (1421lit/Kg of dry matter/day) gave more biogas production when compared to control bioreactor (1007lit/Kg of

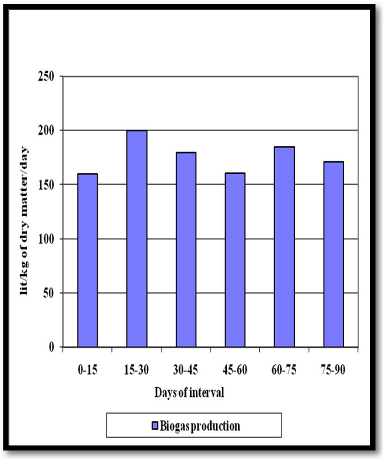
Table 5. Student's "t" test analysis of TS, TVS & VFA for biogas production by gradual reduction of cowdung supplemented with sewage water
Ho: There is significant difference between the production of TS, TVS and VFA in the control and in the experiment

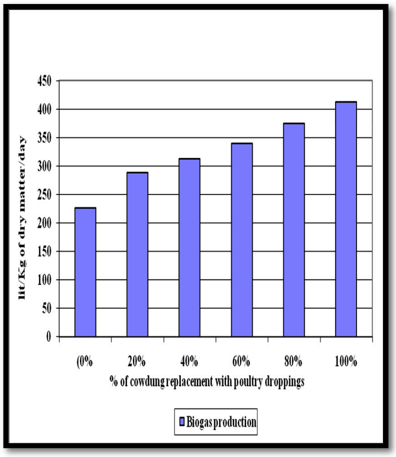
No of days	*Total solids (%TS)		*Total Volatile Solids (%TVS)		Volatile Fatty Acids(%VFA)	
	Control	Experimental	Control	Experimental	Control	Experimental
0	7.6	6.3	62.2	65.8	42.0	52.0
15	7.9	6.6	64.2	66.2	44.0	50.0
30	7.6	6.9	66.2	66.8	40.0	58.0
45	7.6	6.1	64.8	64.9	43.0	48.0
60	7.8	6.8	62.4	72.4	40.0	48.0
75	6.6	7.2	63.8	68.2	40.0	46.0
90	6.4	7.1	64.2	68.8	42.0	52.0
Total	51.5	47	447.8	473.5	291.0	354.0
Mean	7.357	6.714	63.971	67.643	41.5714	50.5714
Varience	0.2622	4.4459	911.905			
					t=2.179	
Standard deviation	0.512		2.109		30.198	
T	t=2.347		t=3.258		t=5.576	

Table value of t at 5% level of significance; Degrees of freedom =12;
*There is a significant difference between the control and experimental bioreactor (p<0.05). Therefore the amount of cow dung replacement with sewage water has a very significant effect on producing total solids, total volatile solids and volatile fatty acids.

dry matter/ day) (Fig. 1) and the maximum gas production was observed during 80% replacement. The maximum biogas production also occurred in that particular level. During 100% replacement, the amount of biogas production becomes lower which in turn indicated that the importance of organic rigid supportiveness and methanogenesis in the biogas production.

In the replacement of cow dung with poultry droppings supplemented with sewage water work also gave high gas production (1952lit/Kg of dry matter/day) than the control bioreactor (1007lit/Kg of dry matter /day) (Fig. 2). And this is concluded that there is an excellent biogas production biogas production in the 100% replacement of cow dung which in turn indicated that poultry droppings contains more total solid level which can be easily degraded by methanogenic organisms and sewage water can be a good nutrient source for biogas production.





X_c =44.94
σ_c=25.23
$C.V_c = \frac{\sigma_c \times 100}{X_c} = 56.14$

X_c =49.66
σ_c=25.07
$C.V_c = \frac{\sigma_c \times 100}{X_c} = 50.48$

Fig. 2. Biogas production in control and experimental bioreactor (Cow dung replacement with poultry droppings and sewage water)

Table 6. Temperature and pH both in control and Experimental bioreactor

Days of Days	Control bioreactor		Experimental bioreactor		Amount of cow dung replacement with sewage water	Experimental bioreactor		Amount of cow dung replacement with poultry droppings
	Temp.(C°)	pH	Temp.(C°)	pH		Temp.(C°)	pH	
0	37	7.2	37	7.0	0%	36	7.1	0%
15	38	7.2	38	7.2	20%	37	7.4	20%
30	37	7.3	37	7.0	40%	37	7.3	40%
45	37	7.1	37	7.2	60%	38	7.5	60%
60	37	7.3	37	7.2	80%	37	7.4	80%
75	36	7.2	36	7.2	100%	38	7.6	100%
90	37	7.2	37	7.0	100%	38	7.7	100%

Mean±SD 36±2.1°C for temperature and 7.2±0.2 forpH.

DISCUSSION

The experiment bioreactors produced more biogas than the control. The gradual replacement of cow dung with sewage water gave maximum gas production at 80% replacement. There are a large number of parameters which affect the net energy output from a digester. Retention time will have an effect on the final gas production as well as the total and volatile solids in the feed materials[27-29]. In the present work the total solids ranged between 6.4% and 7.9% in control and between 6.1% and 7.2% in experimental bioreactor. The total solids value would be about 4% and do not exceed about 9%[30].

The volatile solids do not exceed above 90% or drop below 40% and 73% could be chosen as a reasonable value. In the present study, the maximum volatile solids were 72.8%, it was observed in 80% replacement of cow dung with sewage water which gave more gas

Table 7. Analysis of varience (ANOVA) for the production of biogas between control and experimental bioreactor

Sources of Variation	Degrees of freedom	Sum of squares(x)	sum of squares(y)	Mean sum of squares(x)	Mean sum of squares(y)	Table value of F
Between Means	2	17016.28	19269.21	8508.14	9634.61	3.55
Between products	18	13.55	42.96	0.75	2.39	
Total	20					

Calculated value of F for x and y are greater than that of the table value of F for(2,18) degrees of freedom. There is a significant difference between the control and the experiment. Based on that the further analysis was worked out for the same separately by using student 's t-test.

Table 8. Student's "t" test analysis of TS,TVS&VFA for biogas production by gradual reduction of cowdung supplemented with poltry droppings with sewage water
Ho: There is significant difference between the production of TS,TVS and VFA in the control and in the experiment

No of days	*Total solids (%TS)		*Total Volatile Solids (%TVS)		Volatile Fatty Acids (%VFA)	
	Control	Experimental	Control	Experimental	Control	Experimental
0	7.90	7.22	64.8	74.10	42.6	52.6
15	7.66	7.26	65.20	74.30	46.0	53.8
30	7.66	6.94	65.10	73.70	46.4	52.8
45	7.78	6.92	65.60	73.80	43.2	52.2
60	7.70	6.72	64.76	75.12	44.0	54.0
75	7.60	6.78	67.00	75.24	43.4	53.4
90	7.52	6.78	67.44	75.18	43.8	52.0
Total	53.82	48.62	459.9	521.44	309.4	370.8
Mean	7.689	6.946	65.7	74.49	44.2	52.971
					t=2.179	
Varience	0.0310		0.8129		134.2857	
Standard deviation	0.1760		0.9016		11.5882	
T	t=7.8959		t=18.2402		t=14.16	

Table value of t at 5% level of significance; Degrees of freedom =12;
*There is a significant difference between the control and experimental bioreactor ($p<0.05$). Therefore the amount of cow dung replacement with sewage water has a very significant effect on producing total solids, total volatile solids and volatile fatty acids.

production than other reduction concentration. The influence of temperature on the methanogenic bacterial activity, which inhibit the biodegradation and stabilization efficiency of substrates in bioreactor[31]. In the present work also the mesophilic temperature was provided through out the experimental period and optimum gas yield was also obtained from this temperature.

The temperature fluctuation showed that the bio gas production almost stop and total VFA, such as acetate and propionate are rapidly accumulated, accompanied by the fail in pH. Temperature fall not only affected the methanogenesis but also the hydrolysis and acidification[32]. The maximum gas production occurred in the study of the cattle waste when the total solids are completely degraded. It was true because in the present study, the maximum volatilization of total solid biodegradation occurred during 80% replacement of cow dung by sewage water.

Among the various levels of solid concentration, total solid at 8% registered a higher biogas production or productivity followed by total solid at 6%[33]. In the cow dung replacement with poultry droppings and sewage water study, the reduction of solid occurred up to 6.72% The gas production was found to be maximum in 100% replacement of cow dung with sewage water treated poultry droppings sample which was also in accordance the results of Bonmati *et al*.,(2001)[34]. Many series of experiments for biogas production using cattle, poultry and sewage sludge separately and combinations[35]. Like that in this work, cow dung mixed with poultry droppings supplemented with sewage water gave comparatively maximum biogas yield than control which was loaded with cow dung and ordinary water. Among the various physical parameters, pH is the one which highly influences the microbial activity[36]. The optimum pH for biomethanation ranged between 6.5 and 7.7.[37] The results of the present finding of the experimental bioreactor also depicted the similar results with the maximum gas yield being around neutral pH (Table 8).

CONCLUSIONS

From this study it is well observed that the sewage water which is considered to be the chief source of contamination used as a source of nutrient along with cow dung and poultry droppings for biogas production. Because these animals excrete leads to many problems like odour nuisance, fly nuisance apart from causing serious problems like eutrophication. These substrates act as an alternative renewable energy sources for conventional energy and economically more feasible. After biogas production, the slurry from the biogas plant used as bioorganic fertilizer. Conclusively recycling of these waste materials is necessary to prevent pollution and to conserve natural resources.

ACKNOWLEDGEMENT

I would like to thank the Chairman, Director and Principal of APC Mahalaxmi College for women for providing facilities and their constant encouragement to carry out this research study.

FUNDING

None.

DATA AVAILABILITY

All datasets and statistical report analyses during this study are included in the manuscript.

ETHICS STATEMENT

This article does not contain any studies with human participants or animals.

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