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Solid State Semi-Continuous Anaerobic Digestion of Cattle Dung Supplemented with Poultry Waste

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The present investigation was undertaken with the aim of assessing the impact of retention time period on the biomethanation of cattle dung supplemented with different ratios of poultry waste under semi-continuous solid state fermentation. Cattle dung and poultry waste were mixed in different ratios *viz.*100% Cattle dung (CD), 90% CD +10% Poultry Waste (PW), 80% CD + 20% PW and 70% CW + 30% PW at approximately 17 % Total Solid concentration in 5L aspirator bottles. The digesters were subjected to semi continuous mode of anaerobic digestion and operated for three different retention time (RT) periods of 10 days, 20 days and 30 days. The maximum amount of biogas production was observed in all the digesters during RT of 30 days and the least during the RT of 10 days. Also, the biogas production was maximum in the digester no. 4 (70% CD + 30% PW) and minimum in the digester containing only cattle dung during all the retention time periods. Similar trend was observed in case of enrichment of Nitrogen, Phosphorus and Potassium also with maximum enrichment occurring during RT of 30 days, followed by RT of 20 days and minimum during RT of 10 days.

Key words: Biogas, Solid-state, Cattle dung, Poultry waste, Semi-continuous.

The world now a days is confronted with the trilemma of food, energy and environment. Due to modernization and industrialization the energy requirements are sky-rocketing. Also, due to increasing population there is a very heavy burden on the farmers to produce more food from the already shrinking land resources. All this is resulting in very rapid consumption of the non-renewable energy sources and tremendous amounts of agrochemicals. Both of which is adversely affecting the environment.

Anaerobic digestion of organic wastes is gaining importance due to interest in biogas recovery, production of organic fertilizers and environmental protection. Use of organic manures is an essential approach towards sustainability and conservation of environmental resources with minimum reliance on inorganic fertilizers and maintaining the soil health and productivity[1]. Biogas slurry enriched with poultry waste can be a new source of organic manure in areas where biogas technology is introduced because poultry waste contains higher quantity of N, P and K[2] which are the major plant nutrients. Moreover, the disposal of poultry waste is also troublesome from the point of view odor nuisance and water pollution[3]. It is possible to obtain higher yield of biogas due to enhancement of primary and secondary anaerobic decomposers by use of readily available nutrients in poultry waste. Although many reports of biogas production from poultry waste alone[4] and in combination with other wastes like hog wastes[5] and cattle dung[6] are there, not much work has been done on solid state fermentation of cattle dung mixed with poultry waste.

The conventional biogas technology generally makes use of cattle dung mixed with water

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in the ratio of 1:1. However, the solid state fermentation primarily relies on the moisture present in the substrate itself with minimal requirement of supplementation of water from outside. Hence, this method is very advantageous, especially in the arid and semi- arid regions where scarcity of water is there. This system possesses many benefits like low construction costs and land requirements, apart from having least requirement of water for slurry preparation[7]. The handling of effluent slurry and its subsequent disposal to the fields is also easier as compared to the effluents of conventional systems which tend to solidify into hard moulds thus hampering their uniform application in the fields

MATERIALS AND METHODS

Collection of Materials

Fresh cattle dung was obtained from Animal farm, CCSHAU, Hisar, India and poultry waste was collected from poultry farm, CCSHAU, Hisar, India. They were stored in polythene bags (with their mouth tied) in refrigerator at 4^0 C till further use. Biogas slurry obtained from solid state Janta Biogas Plant of Department of Microbiology, CCSHAU, Hisar, India, was used as source of inoculum.

Biogas production set-up

Two aspirator bottles (capacity 5 L each) were stoppered with rubber corks fitted with glass tubes and connected with rubber tubings. One of the bottles was used as digester and the other was graduated and used as gas collecting bottle. The gas collecting bottle was filled with water. The gas produced in the digester displaced the water in the collecting bottle which was collected in third bottle. The digester was provided with an outlet which was used for feeding fresh materials as well as for withdrawing the digested materials. The outlet was closed with a rubber cork. Anaerobic digestion of cattle dung and poultry wastes was carried out in four digesters containing different ratios of substrates. The details are as follows: Digester 1 - 100% Cattle dung (CD), Digester 2- 90% CD +10% Poultry Waste (PW), Digester 3- 80% CD + 20% PW and Digester 4- 70% CW + 30% PW. All the digesters had approximately 17% Total Solid (TS). The digesters were subjected to semi continuous mode of anaerobic digestion and operated for three different retention time (RT) periods of 10 days, 20 days and 30 days by daily feeding and withdrawing equal amount of substrates depending on different Retention Time (RT) periods.

Analysis of Samples

The pH, Total Solids (TS), Volatile Solids (VS), Carbon content of the samples were estimated by using the standard techniques[8]. Total Nitrogen in the sample was determined by standard micro Kjeldahl method [9].Total Phosphorus content of the sample was determined by method of John [10]. The Potassium content of the sample was determined by method of Antil *et al*[11] using a flame photometer.

RESULTS AND DISCUSSION

Anaerobic digestion was carried out in 5L aspirator bottles by semi continuous mode with retention time periods of 30, 20 and 10 days at approximately 17% TS. This particular TS was selected because the fresh cattle dung contained approximately 17% TS. Similarly Omar *et al.*[12] have also reported 16.7% TS in fresh cattle dung. The composition of influents during different retention time periods were almost similar with respect to various components like Nitrogen, Phosphorus, Potassium, C:N ratio etc (Table -1). The minimum concentration of N, P and K was observed in digester-1 (control) and maximum in the digester - 4 (70% CD + 30% PW), which had the maximum amount of poultry waste which could be correlated to the fact that Poultry waste contains higher concentration of NPK(3.3% -N;1.6%- P; 2.9%-K) as compared to that of cattle dung (1.6%-N; 0.4%- P; 1.5-K)[13].

The samples were collected from each digester after completion of the respective retention time periods and analyzed (Table-2). The total solids concentration decreased in all the digesters during all the retention time periods. During the RT of 10 days, the TS of the effluent of the control was 15.77 % while that of digester -4 (70% CD + 30% PW) was 14.81%. The digesters 2 (90% CD + 10% PW) and 3 (80% CD + 20% PW) had TS concentration of 15.13 and 14.94 % respectively. Thus maximum decrease was observed in digester -4. Maximum percent degradation of TS (31.41 %) was there during retention time period of 30 days in the digester -4

(Table-3). The digesters -1, 2 and 3 showed 11.10, 17.78 and 22.69 % degradation of total solids during RT of 30 days respectively. Decrease in VS was also recorded in all the digesters, with highest percent degradation of 42.11% in the digester no.4 (70% CD + 30% PW) at 30 days of retention time period (Table-3).

The biogas production during various retention time periods was recorded by water displacement method. During 20 days RT a range of 0.18 to 0.30 L/L/ day (control), 0.22 to 0.38 L/L/ day (90% CD + 10% PW), 0.26 to 0.42 L/L/ day (80% CD + 20% PW) and 0.30 to 0.44 L/L/ day (70% CD + 30% PW) volumetric biogas production was observed. Similarly in retention time period of 10 days maximum biogas production was recorded from digester with 70% CD + 30% PW , followed by digester with 80% CD + 20% PW, digester with

Table 1. Average chemical composition of influent slurry at various Retention Time periods.

Parameter	pH	Total Solids (%)	Volatile Solids (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Carbon (%)	C/N
RT-10 days Dig.								
1	7.91	17.22	81.20	1.60	0.45	1.53	47.15	29.47
2	8.09	17.31	79.30	1.78	0.58	1.77	45.99	25.84
3	8.21	17.43	77.82	1.95	0.67	1.98	45.14	23.14
4	8.34	17.47	76.14	2.10	0.77	2.22	44.16	21.03
RT–20 days								
1	8.02	17.49	81.84	1.59	0.45	1.51	47.47	29.85
2	8.15	17.32	78.83	1.78	0.57	1.74	45.73	25.69
3	8.23	17.44	77.49	1.94	0.65	1.96	44.95	23.17
4	8.33	17.19	76.36	2.09	0.78	2.20	44.31	21.20
RT-30 days								
1	7.98	17.29	82.24	1.61	0.43	1.54	47.70	29.63
2	8.11	17.21	78.52	1.77	0.57	1.75	45.56	25.74
3	8.25	17.32	77.36	1.94	0.65	1.98	44.87	23.13
4	8.34	17.13	76.43	2.08	0.75	2.19	44.33	21.31

Table 2. Chemical composition of effluent slurry at various Retention Time periods

Parameter	pH	Total Solids (%)	Volatile Solids (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Carbon (%)	C/N
RT-10 days Dig.								
1	7.52	15.77	79.28	1.74	0.49	1.67	45.98	26.43
2	7.44	15.13	75.93	2.02	0.66	2.03	44.04	21.76
3	7.48	14.94	72.57	2.25	0.78	2.31	42.15	18.7
4	7.54	14.81	70.56	2.44	0.91	2.52	40.93	16.77
RT–20 days								
	7.76	15.75	79.45	1.76	0.50	1.68	46.08	26.18
1	8.09	14.72	74.53	2.08	0.67	2.05	43.69	21.00
2	8.00	14.42	71.31	2.32	0.78	2.34	41.94	18.08
3	8.22	13.80	70.18	2.55	0.97	2.74	41.87	16.42
4								
RT-30 days								
1	7.75	15.37	77.30	1.80	0.48	1.73	44.84	24.91
2	7.98	14.15	72.17	2.14	0.69	2.12	41.86	19.59
3	8.06	13.39	68.30	2.46	0.84	2.56	39.62	16.11
4	8.19	11.75	64.50	2.85	1.09	3.18	37.41	13.13

90% CD + 10% PW and minimum in the control. The average volumetric biogas production was 0.257 L/L/ day (control), 0.346 L/L/ day (90% CD + 10% PW), 0.371 L/L/ day (80% CD + 20% PW) and 0.397 L/L/ day (70% CD + 30% PW) during 30 days retention time (Table-4). The average volumetric gas production was lesser during 20 days RT and least during RT of 10 days in all the digesters. Solid conversion efficiency of 0.011, 0.019, 0.022 and 0.029 L/ g TS added / day was observed in the digesters at 10 days RT (Table- 4). However, at longer retention times higher efficiency was observed both in terms of biogas produced/ g TS added/day as well as biogas produced/ VS added/ day. Thus at higher loading rates, lower yield of biogas was observed. This is agreement with Alvarez and Lidén[14] who also observed decrease in biogas yield at higher loading rates. Li and Zhang[15] also reported decrease in biogas production on increasing the loading rate from 3 to 4 g VS/L / day during digestion of dairy waste water by Anaerobic Sequencing Batch Reactor.

In all the retention time periods the maximum biogas production, degradation of TS as well as VS was observed in the digester -4 (70% CD + 30% PW). This digester contained greater

Table 3. Percent degradation of various constituents during different retention time periods

	Digesters											
	1	2	3	4	1	2	3	4	1	2	3	4
Parameter	RT -10 days				RT – 20 days				RT – 30 days			
Total Solids	8.42	12.59	14.28	15.23	9.95	15.01	17.31	19.72	11.10	17.78	22.69	31.41
Volatile Solids	10.68	16.31	20.7	21.44	12.58	19.64	23.91	26.25	16.44	24.43	31.74	42.11

Table 4. Volumetric biogas production & digestion efficiency of CD & PW during semi continuous digestion at various retention periods

	Digesters											
	1	2	3	4	1	2	3	4	1	2	3	4
Parameter	(RT- 10 days)				(RT- 20 days)				(RT- 30 days)			
1) Organic Loading Rate												
g TS / L / day	12.39	12.46	12.55	12.58	6.29	6.15	6.28	6.18	4.15	4.13	4.16	4.11
g VS/ L / day	10.07	9.88	9.76	9.58	5.15	5.01	4.86	4.71	3.41	3.24	3.22	3.14
2) Volumetric Biogas production(L/L/day)	0.142	0.232	0.282	0.362	0.230	0.303	0.357	0.389	0.257	0.346	0.371	0.397
3) Solid Conversion Efficiency												
L/ g TS added /day	0.011	0.019	0.022	0.029	0.037	0.048	0.057	0.063	0.062	0.084	0.089	0.097
L / g VS added /day	0.014	0.023	0.029	0.038	0.045	0.061	0.073	0.083	0.075	0.107	0.115	0.126

Table 5. Improvement in fertilizer value of biogas slurry at various Retention time periods during semi continuous digestion of Cattle Dung and Poultry Waste

	Retention Time Periods (Days)								
	10			20			30		
Parameters	N	P	K	N	P	K	N	P	K
Digesters									
1	8.75	9.11	9.2	10.06	11.11	11.05	11.80	12.56	12.59
2	13.7	14.45	14.48	16.85	17.54	17.70	20.73	21.57	21.54
3	15.58	16.72	16.67	18.39	19.53	19.58	26.80	29.69	29.39
4	16.19	17.92	18.02	22.01	24.61	24.55	37.02	45.87	45.21

concentration of poultry waste and hence the elevated levels of nutrients (Table-1) might be the reason behind increased microbial activity resulting into greater degradation of solids and consequently higher biogas yield. Singh *et al*[16] also observed higher biogas production and greater degradation of solids in digester containing mixture of cattle dung and poultry waste as compared to cattle dung alone.

The digester effluents had elevated levels of Nitrogen, Phosphorus and Potassium as compared to the influents (Table-1 and 2). Maximum increase was observed during retention time period of 30 days, followed by 20 days RT and minimum enrichment was observed in 10 days RT (Table- 5). Digester -1 showed 12.56 % increase of Phosphorus and 11.80 % increase of Nitrogen and in digester - 4 (with 30 % poultry waste) 37.02 % increase of Nitrogen and 45.87 % increase of Phosphorus was recorded during 30 days RT. During the anaerobic digestion the Phosphorus and Potassium remain stable but since dry matter (TS) decreases in the digested effluent, their concentration increases after digestion when expressed as % dry matter content (Demuynck, 1984). So, there is no net increase or decrease in Phosphorus and Potassium content. As far as Nitrogen is concerned, a part of organic-N is converted to ammonical- N form, so a net loss of Nitrogen is there. Therefore, the percentage increase of Nitrogen was lesser as compared to Phosphorus and Potassium (Table- 5). But, due to VS degradation and consequent decrease in Carbon content and increase in % N (as % TS) the C:N gets narrowed. The greater increase of NPK in digester-4 could be correlated with higher degradation of Total Solids (TS).

Among anaerobic digestion at various RT's, digester-4 (70 % cattle dung + 30 % poultry waste) showed maximum biogas production which could be correlated to maximum degradation of TS and VS and highest solid conversion efficiency. Maximum enrichment of NPK was obtained in RT of 30 days in digester-4. This could be attributed to the fact that highest amount of degradation of TS was there in the same digester.

Thus, the ddition of poultry waste to cattle dung proved to be beneficial both from the point of view of biogas production as well as increase in the plant nutrient (NPK) content of effluent slurry. Also, better results were obtained on increasing the concentration of poultry waste (up to 30 %). The retention time period of 30 days was found to be optimum in the present investigation. However, more investigations need to be conducted to assess the impact of still higher concentrations of poultry waste and enhanced retention time periods.

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