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Paddy Straw Supplementation to Cattle Dung for Enhanced Biogas Production and Enrichment of Effluent Slurry

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Biogas production on supplementation of paddy straw to cattle dung under semi-continuous system was carried out at 14-15% total solids concentration under laboratory conditions. Supplementation of 5% paddy straw to cattle dung led to maximum biogas production of 53.7 l/kg with volumetric productivity of 0.460 l/l/day accompanied by 24.0 and 26.4% degradation of total and volatile solids respectively. The C/N ratio of effluent slurry after 5% paddy straw supplementation to cattle dung was 30.7 that reduced to 21.9 on composting with *Trichoderma reesei* for one month resulting in the production of quality manure.

Key words: Biogas, Cattle dung, Paddy straw, Semi-continuous.

Adequate and uninterrupted supply of energy is the basic demand for economic growth and development of any country. The basic problem we face today is that the earth's natural sources of energy are being depleted at a most alarming rate but our conventional energy resources are limited and already have been over exploited so there is need to look up for alternate sources of energy. Motivated by the need to meet the ever-increasing energy demand and sustainability consciousness, many Governments have promoted renewable energy technologies such as biogas. Biogas technology couples the advantage of renewable alternatives with strong potential and environment sustainability (Abdullahi *et al*, 2011). Biogas (a mixture of approximately 60% methane and 40% carbon dioxide) is a well-established fuel that can supplement as an energy source for cooking and lighting in developing countries. A variety of organic wastes are used as raw materials for biogas production. Most of the biogas plants in India are being operated with diluted cattle dung slurry at 7-8% total solid concentration. Due to constraints in these conventional biogas systems, solid state fermentation system operated at about 15% total solid concentration using cattle dung as substrate has come into existence (Wati *et al*., 2009). Availability of animal waste is one of the major problems for successful operation of biogas digesters so researchers are looking towards other alternative substrates. Agricultural residues represent the most important energy sources readily available for biogas production and paddy straw is one of such residue. Paddy straw as such cannot be used as raw material for biogas production because bacteria cannot easily break down its cellulose due to complex physical and chemical structure of lignocellulosic biomass as well as gas production yield is low compared to other available raw materials although paddy straw is the most available material in the country. (Yanfeng *et al*, 2009). Paddy straw in India is generated in huge amount and its management for farmers has become a big challenge so it is burnt. To reduce environmental pollution and to supply sufficient biogas production necessitated this study, with the ultimate goal of assessing the effect of co-digestion of cattle dung and paddy straw on biogas production.

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MATERIALS AND METHODS

Substrates

Paddy straw was collected from farmer's field and fresh cattle dung was obtained from animal farm of College of Animal Sciences, LUVAS, Hisar . To mix paddy straw with cattle dung it was first chopped to 2-3 cm pieces using Wiley type grinder. It was then soaked overnight and excess water was drained before use. Mixture of cattle dung and paddy straw was prepared in different ratio's 1:00, 1:0.31, 1:0.46 1:0.63, and 1:0.78 on dry matter basis corresponding to 0, 5, 7.5,10 and 12.5 % on fresh weight basis (Table 1).

Anaerobic digestion

Cattle dung and paddy straw mixtures were digested in semi continuous mode for ten weeks. The laboratory digesters comprised of 5 litre capacity aspirator bottles fed with cattle dung alone (digester 1) and cattle dung mixed with different concentrations of paddy straw (5-12.5%, digesters 2-5) at 14-15% total solid (TS) concentration. Three kg of each mixture was filled in respective digester bottles along with 10% inoculum from running biogas plant. About 300g substrate in each digester was replaced with same amount of fresh substrate weekly and gas production was recorded for ten weeks by water displacement method. The temperature in this study ranged from 31-36 °C.

Composting

Composting of spent substrate after biomethanation was carried out in enamel trays (48 x42 x5 cm). Spent substrate was mixed with *Trichoderma reesei* culture (10%) and covered with polythene sheets. Moisture was maintained 60% and after one month analysis of compost was done for various parameters using standard methods.

Analysis

Analysis of influent and effluent was done for total solids (TS), volatile solids (VS), cellulose, hemicellulose, lignin and total N, P and K using standard methods (AOAC, 1970). The methane content in biogas was determined by gas liquid chromatography using porapaq column and thermal conductivity detector.

RESULTS AND DISCUSSION

Biogas production and digestion efficiency are dependent on the type of substrate and its composition (Li and Zhang, 2004). Analysis of cattle dung revealed 48.1% organic carbon and C/N ratio of 34.3 but paddy straw had higher organic carbon and C/N ratio (Table 2). The C/N ratio of 15:1 to 25:1 is reported to be ideal for biogas production from cattle dung and other substrates but the fermentative bacteria use carbon 25-30 times as fast as nitrogen thus necessitating the optimum C/N ratio of 30 to 35:1. Deviation from this ratio slows down the process suggesting that paddy straw can be used as substrate only after C: N ratio adjustment (Svensson *et al.*, 2006).

Paddy straw was supplemented with cattle dung for C: N ratio adjustment. Paddy straw supplementation to cattle dung resulted in enhancement in biogas production. Cumulative biogas production of 125.8-161.1 l was observed in different digesters after 10 weeks of semi continuous digestion (Fig.1). Maximum biogas production of 161.1 l/kg was observed on supplementation of cattle dung with paddy straw at 5% level and further increase in paddy straw supplementation did not have appreciable effect on biogas production that might be due to nutrient limitation or high C: N ratio (Kumari *et al.*, 2012). Iyagba *et al.*, (2009) reported cumulative biogas production of 161.5 ml after 38 days from a sample

Table 1. Composition of different digesters for biogas production

Digester	Description
1	3 kg CD (Cattle Dung), (control), (1: 00)
2	3 kg CD + 150 g Paddy straw, (1: 0.31)
3	3 kg CD + 225 g Paddy straw, (1: 0.46)
4	3 kg CD + 300 g Paddy straw, (1: 0.63)
5	3 kg CD + 375 g Paddy straw,(1: 0.78)

Table 2. Analysis of cattle dung and paddy straw

Parameter	Cattle dung	Paddy straw
Cellulose (% of TS)	26.7	33.0
Hemicellulose (% of TS)	19.2	22.2
Lignin (% of TS)	14.8	6.10
Nitrogen (% of TS)	1.40	0.75
Phosphorus (% of TS)	0.55	0.11
Potassium (% of TS)	1.60	0.74
Organic carbon (%)	48.1	51.1
C/N ratio	34.3	68.2

of cow dung and rice husk at 8% total solid concentration.

Solid conversion efficiency of 0.358 l/g TS and 0.418 l/g VS was observed on 5% supplementation of paddy straw to cattle dung that was 0.281 l/g TS and 0.339 l/g VS added for cattle dung only (Table 3). Bhattacharya and Mishra (2003) reported maximum biogas production of 0.160 l/l/day with digestion efficiency of 0.654 l/g TS added at mesophillic temperature from cattle dung mixed with agricultural residues in 3:2 ratio Analysis of biogas revealed about 61% methane. Banik, 2004 reported that biogas containing 55-65% methane can be produced from lignocellulosic wastes by anaerobic fermentation using cattle dung as sole source of inoculum.

Co-digestion of cattle dung and paddy straw resulted in degradation of total and volatile solids. Maximum degradation of TS (24%) and VS (26.4%) was also observed on supplementation of 5% paddy straw to cattle dung (Table 4). Increased biogas production on 5% paddy straw supplementation to cattle dung led to greater degradation of solids.

The effluent after co-digestion of cattle dung and paddy straw had C/N ratio between

Table 3. Digestion efficiency of co digestion of cattle dung and paddy straw during semi continuous digestion of ten weeks at 14- 15% total solids

Parameter	Digesters				
	1	2	3	4	5
Total biogas production (l/kg)	41.86	53.70	49.26	46.70	45.26
Volumetric production (l/l/day)	0.358	0.460	0.422	0.400	0.388
Solid conversion efficiency					
l/g TS added	0.281	0.358	0.332	0.331	0.318
l/g VS added	0.339	0.418	0.385	0.378	0.363
% Methane in biogas	61.7	61.3	61.1	61.5	61.2

Table 4. Chemical degradation of substrate and C/N ratio after co digestion of cattle dung and paddy straw during semi continuous digestion of ten weeks at 14- 15% total solids

Digester	Total Solids (%)			Volatile Solids (%)			C/N ratio	
	Initial	Final	Degradation	Initial	Final	Degradation	Initial	Final
1	14.9	12.6	15.4	83.0	81.0	17.4	34.3	29.1
2	15.0	11.4	24.0	85.5	82.7	26.4	8.4	30.7
3	14.8	12.1	18.2	86.3	84.0	20.4	41.3	33.8
4	14.1	12.2	17.5	87.4	82.0	18.8	42.9	34.8
5	14.2	11.9	16.1	87.7	85.9	17.9	43.8	36.5

Table 5. Analysis of spent substrate after composting with *Trichoderma reesei* for one month

Parameters	Treatments							
	CD + 5% PS		CD+7.5% PS		CD+ 10 % PS		CD +12.5%PS	
	Without fungus	With fungus	Without fungus	With fungus	Without fungus	With fungus	Without fungus	With fungus
Nitrogen (% of TS)	1.29	1.77	1.21	1.90	1.18	1.71	1.16	1.67
Phosphorus (% of TS)	0.53	0.51	0.45	0.43	0.43	0.42	0.42	0.42
Potassium (% of TS)	1.57	1.56	1.55	1.54	1.53	1.52	1.51	1.51
Organic carbon (%)	47.9	42.1	48.7	41.7	48.1	42.6	49.3	41.3
C/N ratio	30.7	21.9	33.8	23.7	35.6	24.9	33.5	24.7

29.1-36.5 and the ideal C/N ratio of compost lies between 18-20:1 (Garcia *et al*., 1992) suggesting that it can be further degraded for quality manure production. Inoculation of cellulolytic microorganisms has been reported to enhance rate of decomposition (Gaind *et al*., 2005). To explore further composting of spent substrate cellulolytic fungus *Trichoderma reesei* was used. Inoculation of *T. reesei* to spent substrate and incubation for one month resulted in mineralization of more nitrogen as a result, reduction in C:N was also faster than control thus reduction in C/N ratio upto 21.9 was observed (Table 5). Total phosphorous and potash content remained stable during composting process suggesting that *Trichoderma reesei* which is rich in lignocellulolytic enzymes, hastened the process of decomposition which ultimately reduced the loss of nutrients through leaching and volatilization thus production of quality manure.

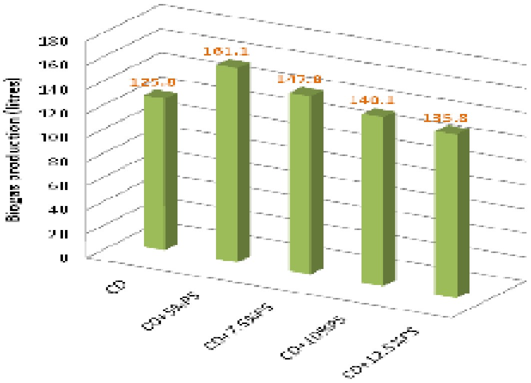

Fig. 1. Cumulative biogas production from cattle dung supplemented with paddy straw during semi-continuous digestion at 14-15% total solids

CONCLUSION

Supplementation of paddy straw to cattle dung proved to be beneficial to achieve enhanced biogas production and improved the quality of manure.

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