© Applied Science Innovations Pvt. Ltd., India Carbon – Sci. Tech. 7/2(2015)122-129

Carbon – Science and Technology

ISSN 0974 – 0546

http://www.applied-science-innovations.com

ARTICLE Received: 16-12-2014; Accepted: 31-12-2014

Enhancing anaerobic digestion of poultry litter in field digestors by incorporating in-line pre-digestor assembly

M. J. Barooah[1], A. Borah[1], M. Dutta[2]

[1] Department of Agricultural Engineering, Assam Agricultural University, Jorhat, Assam, India.

[2] Department of Chemistry, Mariani College, Assam, India.

Email: abhijit64@gmail.com

Abstract: Anaerobic fermentation inside the digestor is the continuous process which results in the formation of useful biogas fuel. All feedstocks are not easily decomposable thereby necessitating the design of an "optional in-line pre-digestor assembly". Initially a 2 m^3 modified fixed dome 'Deenbandhu' type biogas plant was commissioned with cattle dung, bypassing the pre-digestor assembly. In a phased manner, cattle dung was substituted with poultry litter as feedstock. Gradually increasing the substitution @ of 10% per fortnight, complete substitution of cattle dung could be attained in 18 week time. Poultry droppings assorted with paddy husk from deep litter system of poultry housings were used as feedstock. As paddy husk were indecomposable inside the digestor, an in-line pre-digestor assembly was used to remove the unwanted paddy husk by water dissolution technique. Enzymatic hydrolysis initiated in the pre-digestion tank in the 24 hours residence time improved the digestibility of the feedstock for generating biogas. The process of cattle dung substitution with poultry litter was complete in 18 weeks duration. Daily gas production was recorded with the help of wet type gas flow meter. The gas produced was continuously used for domestic cooking. The total solid (TS) content of the poultry litter based feedstock slurry was maintained at around the same TS (9 - 10%) as that of cattle dung (dung to water at 1:1 ratio) slurry. With 100% use of poultry droppings at 10.3 % TS, average gas production level was 208.5 lit per kg of TS.

Key words: Food waste, septage, anaerobic, co-digestion, energy, biogas, methane

---

1. Introduction:

Energy has always been a driving force for a successful farming system. At present, government policy is to minimize fossil fuel use and shift to clean renewable energy. Research work in this line needs attention[1]. Biogas is a renewable energy derived from organic matter, primarily cattle dung or any other agro-residue and is used for cooking, lighting, running irrigation pump sets or in the generation of electricity. Leftover digested slurry is used as manure for crop production. The concentration of ammonia nitrogen is important when considering Biogas production from Broiler farm litter (BFL). During anaerobic digestion of any poultry litter, the concentration of endogenous ammonia - nitrogen rises considerably. An excess of ammonium inhibit - the destruction of organic compounds, the production of volatile fatty acids and subsequently methanogenesis [2].

In the North-East India a broiler farm is a meaningful component of a farming system. The poultry housing is primarily of deep litter system. In deep litter system of poultry housing of North-East India, bedding material used is mainly paddy husk. Poultry birds mostly broiler chicken rest, defecate and urinate in the husk itself. Dry husk absorbs the defecated liquid portion and assimilate the dry portion in such a way that proper hygiene is maintained for the birds. The moisture content of fresh husk used as bedding material is maintained at around 15 to 20%. Optimum depth of bedding material is maintained so as to absorb the chicken litter. In earthen floored poultry houses, the bedding material needs to be changed frequently during rainy months owing to high atmospheric relative humidity. From these farm units, deep litter generated and removed periodically is a good substrate for biogas production to meet the energy requirement of the farm.

Experimental details and results of pilot level investigations of anaerobic digestion of segregated poultry litter from deep litter housing, conducted in upper Brahmaputra valley zone of North East India are reported here.

2. Methods and Materials:

The Broiler Farm Litter includes a mixture of excreta (manure), bedding material or litter (e.g. rice husk), waste feed, feathers, grit - removed periodically from poultry houses. The litter and manure component of this waste has a high nutritional value and can be used as an organic fertilizer, thus recycling nutrients such as nitrogen, phosphorous and potassium into the soil. Traditionally BFL from cage type housing contains very little quantity of bedding material in it whereas waste generated in deep litter system contains bedding material like – husk in the ratio of 1:1(Excreta : husk). Traditionally poultry waste generated is land spread. Poultry waste contains paddy husk which is difficult to decompose. Over a time period deep litter waste piles up in the farmer's yard and creates an environmental nuisance. This waste generated cannot be applied as plant nutrient but lead to an enrichment of water nutrients resulting in eutrophication of nearby water bodies, spread of pathogens, and production of phytotoxic substances, air pollution and emission of greenhouse gases. Excessive application of poultry litter in crops can result in nitrate (NO_3) contamination of groundwater and high levels of NO_3 in drinking water can cause methaemoglobinaemia (blue baby syndrome), cancer, and respiratory illness in humans [3]. Chemical and physiochemical characterisation of poultry manure are summarised in Table 1 [4]. Searching for an environmentally acceptable disposal route among the option of - anaerobic digestion, composting and direct combustion, anaerobic digestion of poultry waste to generate energy with easy to handle organic manure as a by-product proves to be the best [5]. Common problems experienced by the current technologies are the existence and fate of nitrogen as ammonia, pH and temperature levels, moisture content and the economics of alternative disposal methods [6].

Table 1 Chemical and physiochemical characterisation of poultry manure

Contents	Solid poultry manure
Organic matter, % dry matter	85.38
pH	8.8
Moisture, % wet weight	48.69
Total nitrogen, % dry weight	3.56
Inorganic nitrogen, % dry weight	1.74
Ammonia nitrogen, % dry weight	1.76
OCC/Nitrogen ratio	10.89
TCC/nitrogen ratio	12.24

P_2O_5, % dry weight	0.71
K_2O_5, % dry weight	3.79

A study was done by varying the amounts of fresh chicken manure and anaerobically digested sludge (poultry manure stored anaerobically for half a year) to investigate the highest solids level at which digestion was still feasible. The efficiency of conversion to methane was found to decrease with increasing organic loads to the digester. The highest solids content at which digestion was successful was approx. 10% total solids [7]. Another investigation found that methane yield decreased after a threshold of 5% total solids was reached. The same investigation provided evidence that methane yield from the anaerobic digestion of poultry waste was higher than that from the digestion of piggery and cattle waste [8]. Similar work agreed with these findings [9]. The dry fermentation of chicken manure for production of methane in mesophilic conditions at 37^0 C was studied under laboratory conditions using a repeated batch culture system and found that spontaneous acclimation of the methanogenic consortia to high levels of ammonia could occur resulting in production of methane even under a high percentage of total solid (25%) as well as a high level of ammonia [10].

The inlet of a family size biogas plant was designed with a pre-digestor with the facility of feeding cattle dung alone, combination of cattle dung and poultry litter (during substitution) and poultry litter alone (after substitution). BFL was removed from the lumps by water dissolution technique in a pre-digestion tank (Fig 1). Lumps were allowed to be dissolved in water for a period of 24 hours with intermittent stirring. Standard size mesh (49 mesh/cm^2) was used to physically remove the husk from the lumps. Dissolved litter was let into the biogas plant from the pre-digestion tank and husk struck in the mesh was removed physically.

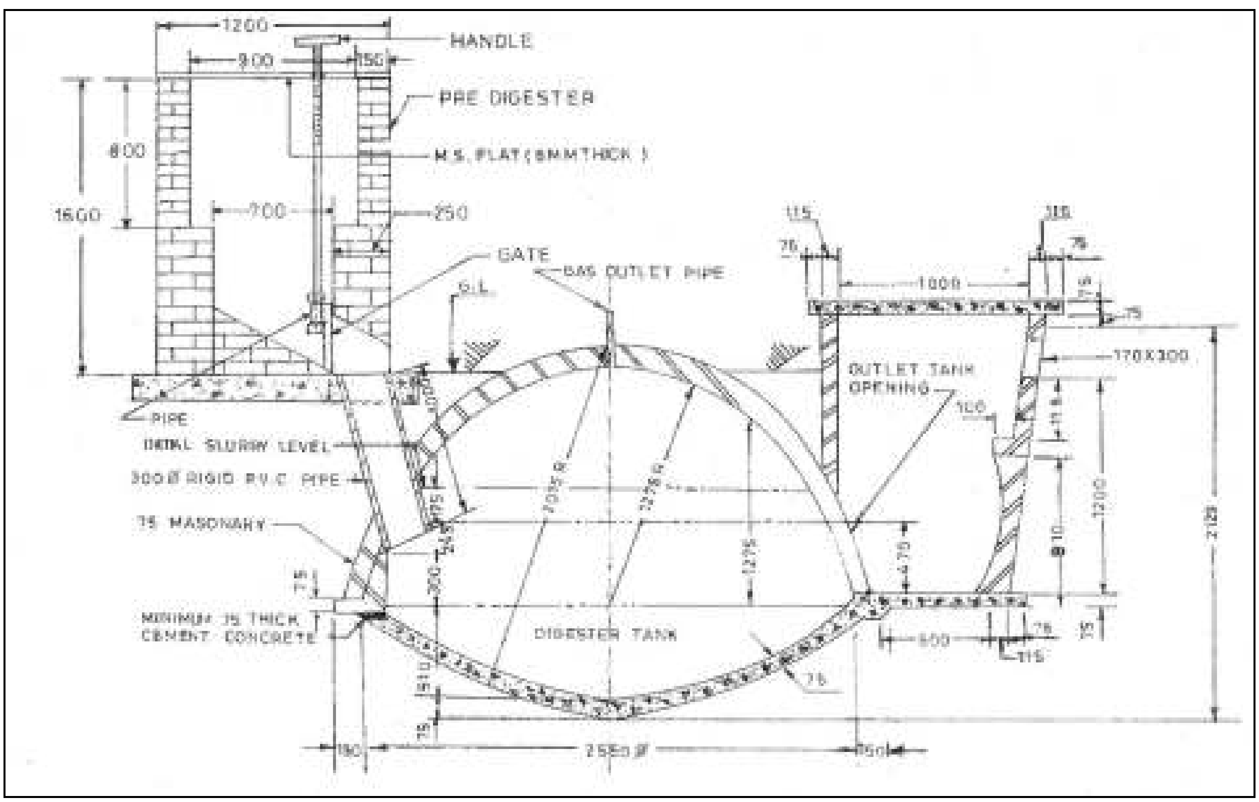

Fig. 1 Sectional view of $2m^3$ biogas plant and the Pre-Digestor assembly.

3. Results and Discussion:

The physical and chemical characteristics of BFL were analyzed (Table 2). The semi-continuous type biogas plant was initially charged only with cattle dung till stabilization. Thereafter cattle dung was gradually replaced with BFL. Over a period of 18 weeks, Cattle Dung was completely substituted with BFL. Hereafter, the plant ran only on BFL. The gradual substitution helped in acclimatization of methanogenic consortia to high ammonia levels exhibited by stable gas production and other bio-chemical characteristics.

Table 2 Chemical and physiochemical characteristics of poultry manure used.

Parametres	Poultry
Total Solids %	32.28
Volatile solids % of TS	83.03
N %	2.01
P_2O_5	1.42
K_2O	0.82
pH	6.48

The present investigation was carried out with a family sized Deenbandhu type cattle dung based biogas plant. In the biogas plant, dung to water was in the ratio of 1:1 so as to maintain about 8-9% total solid (TS) during anaerobic digestion of cattle dung. Design modifications were incorporated so that BFL (after pre-digestion) and cowdung could be fed through two different inlets (Fig 2). In the modified 2 m^3 plant, initial charging was done with cow dung @ 50 kg per day maintaining dung-water ratio of 1:1 till the stabilization of the plant was attained. Stabilization of the plant took 58-60 days after initial charging. Normal gas production and movement of slurry through the outlet indicated the stabilized condition.

Cattle dung was directly fed into the plant without using the pre-digestor. While using poultry dropping as substrate, the functioning of the pre-digestor is essential. In view of the deep litter system of poultry rearing in use, the pre-digester assembly was designed taking into consideration the separation of paddy husk from the poultry droppings before it is fed into the main digestor.

Figure (2): Side and front view of 2 m^3 plant with Pre-digestor assembly.

The following design considerations were done in the construction of the pre-digestor:

a. Composition of the litter bedding ready for disposal.

b. Volumetric space for one day's feedstock (poultry litter) + assorted paddy husk + measured quantity of water.
c. Removal of droppings from paddy husk after 5 to 10 number of stirrings and left for 24 h
d. The husk is removed from the mixture by a PVC sieve attached from the top of the pre diegestor.

As high nitrogen content in BFL inhibits methanogenesis so the plant was initially commissioned and run with cattle dung till it attained steady-state slurry movement as well as stable gas production. Thereafter switching over of the substrate from cow dung to BFL was carried out. The schedule of cow dung substitution with poultry dropping is shown in Table 3. The schedule of substitution was carried out in accordance with TS content of cattle dung substituted (Column 4) with corresponding quantity of BFL TS (Column 6).

A schedule was prepared (specifically for deep litter system of poultry housing) which served as a ready reckoner of Broiler dropping + paddy husk type discarded bedding material along with the quantity of water required at different weeks corresponding to different level of substitution respectively. This type of feeding was possible only for the design of the in-line pre-digestor assembly. For both poultry and cattle – dung-water ratio was maintained at 1:1. Broiler dropping was detached from the husk by water dissolution technique followed by 5 to 10 no. of stirrings and left for 24 h before it was fed into the digestor. Daily gas production record was maintained while substitution was in progress.

Table (3): Schedule of cattle dung substitution with poultry litter " Ready Reckoner".

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Percent Replacement of cattle dung With poultry litter	Time in Weeks	Broiler litter + husk (in Kg)	Broiler litter-TS (in Kg)	Cattle dung (in Kg)	Cattle Dung TS to be substituted (in Kg)	Water added In cattle dung (in lit)	Water added in BFL stock (in lit)	Total water added (in lit)
10%	0	3	0.96	45	0.9	45	10	55
20%	2	6	1.95	40	1.8	40	20	60
30%	4	9	2.9	35	2.7	35	25	60
40%	6	12	3.9	30	3.6	30	35	65
50%	8	15	4.9	25	4.5	25	45	70
60%	10	18	5.8	20	5.4	20	55	75
70%	12	21	6.8	15	6.3	15	60	75
80%	14	25	8.1	10	7.2	10	75	85
90%	16	28	9	5	8.1	5	85	90
100%	18	32	10.3	0.0	0.0	0	95	95

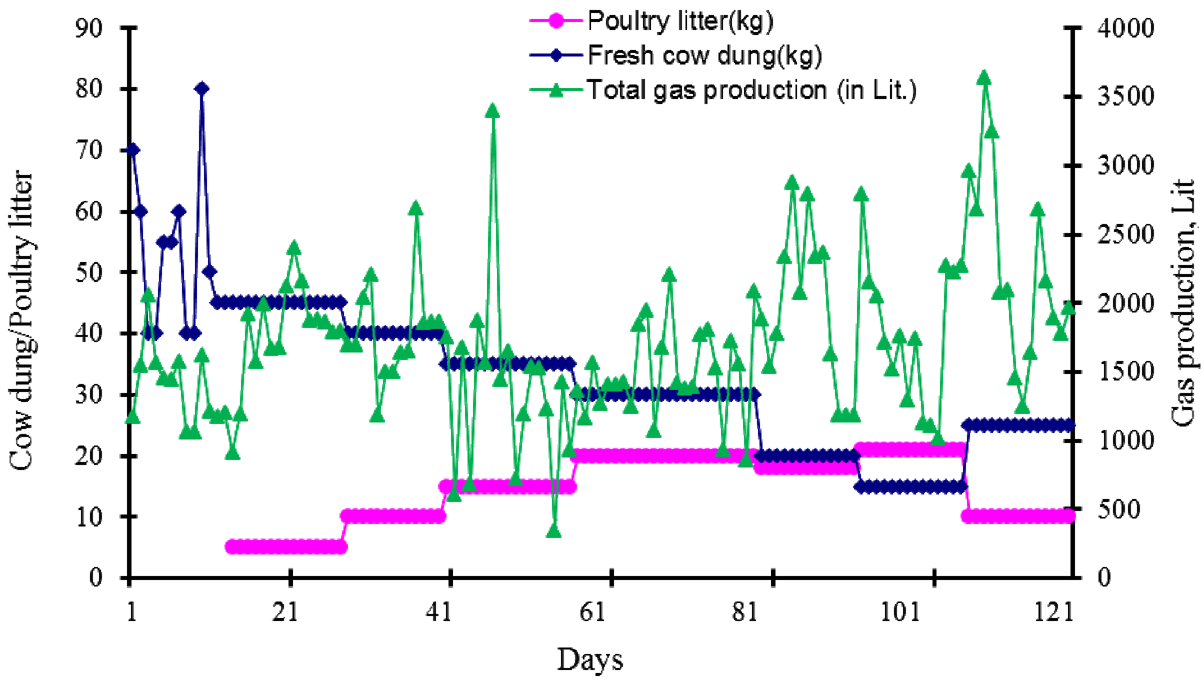

Figure (3): Daily gas production in response to feed stock substitution of cowdung with BFL.

Gas production records (Fig. 3) show that substitution of cowdung with BFL had no adverse effect on biogas production. The gradual substitution of cowdung with BFL (in TS) was well exhibited with step down and step up graphs respectively. The feeding of the plant was facilitated by the in-line pre digestor assembly. Biogas production as high as 3615 lit/day was recorded with 50% substitution of cowdung with BFL.

With 100% use of BFL at 10.3 % TS, average gas production level attained is presented (Figure 4). The analysis of biochemical changes of cow dung and poultry litter in particular before and after digestion underpins the anerobic fermentation process inside the Biogas digestor (Table 4).

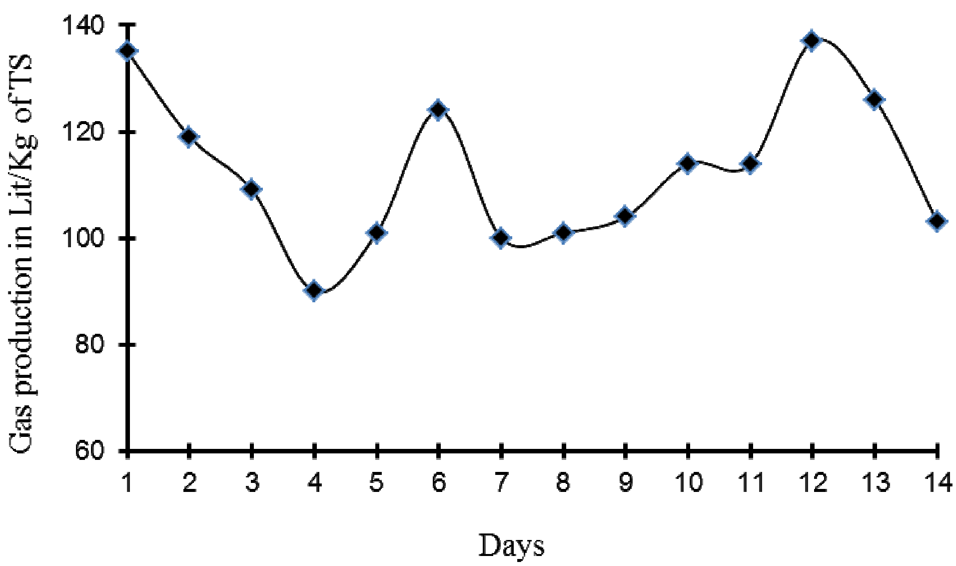

Figure (4): Average gas production from only Broiler farm litter.

This investigation had proved that BFL is a good substrate for methane production, provided the technology of phase wise cattle dung substitution with BFL is practiced in a biogas plant initially charged with cattle dung. In addition the plant design should be such that it incorporates an in-line pre-digestor for smooth feeding of the plant.

Table (4): Biochemical changes in cowdung and BFL during gas production.

Parametres	Cow dung		Poultry	
	Inlet	Outlet	Inlet	Outlet
Total Solid %	18.57	7.80	32.28	11.29
Volatile solid %	84.85	70.03	83.03	67.42
pH	7.04	7.21	6.48	7.01
N %	0.92	1.60	2.01	2.06
P_2O_5 %	0.46	0.88	1.42	1.48
K_2O	0.78	1.10	0.82	0.91

4. Conclusions: As high nitrogen content in BFL inhibits methanogenesis so the plant was initially commissioned and run with cattle dung till it attained steady-state slurry movement as well as stable gas production. This investigation has proved that BFL is a good substrate for methane production. While using poultry dropping as substrate the functioning of the pre-digestor is essential. The biochemical changes of cowdung and BFL in particular, before and after digestion underpins the anaerobic fermentation process inside the digestor. Dairy and Broiler farming both being economically viable component of the farming system, BFL could effectively be used in biogas plants for its sustainability.

Acknowledgement: The scientific work was carried out under All India Coordinated Research Project (ICAR) on Renewable Energy Sources operative under Assam Agricultural University, Jorhat. The authors acknowledge the facilitation and support of both the institutions.

Referances:

1. B. Kumar and P. Kumar, Green economy: Policy framework for sustainable development, Current Science, 100/7 (2011) 961 – 962.
2. N. I. Krylova, R. E. Khabiboulline, R. P. Naumova, and M. Nagle, The influence of ammonium and methods for removal during the anaerobic treatment of poultry manure, J. Chem. Technol. Biotechnol. 70 (1997) 99–105.
3. C. C. Bitzer, J. T. Sims, Estimating the availability of nitrogen in poultry manure through laboratory and field studies, J. Environ. Qual. 17 (1988) 47–54.
4. E. Guerra-Rodriguez, M. Diaz-Ravina, and M. Vazquez, Co-composting of chestnut burr and leaf litter with solid poultry manure, Bioresour. Technol. 78 (2001) 107–109.
5. F. J. Stevenson, Cycles of Soil. (1986) Wiley, New York.
6. B. P. Kelleher, J. J. Leahy, A. M. Henihan, T. F. O'Dwyer, D. Sutton, and M. J. Leahy, Advances in poultry litter disposal technology – a review, Bioresour. Technol. 83 (2002) 27–36.
7. G. Bujoczek, J. Oleszkiewicz, R. Sparling, and S. Cenkowski, High solid anaerobic digestion of chicken manure, J. Agr. Eng. Res. 76 (2000) 51–60.

8. I. N. Itodo, and J. O. Awulu, Effects of total solids concentrations of poultry, cattle, and piggery waste slurries on biogas yield, Trans. ASAE, 42 (1999) 1853–1855.

9. F. J. Callaghan, D. A. G. Wase, K. Thayanithy, and C. F. Forster, Co-digestion of waste organic solids: batch studies, Bioresour. Technol. 67 (1999) 117–122.

10. F. Abouelenien, Y. Nakashimada, and N. Nishio, Dry mesophilic fermentation of chicken manure for production of methane by repeated batch culture, J. Biosci. Bioeng. 107/3 (2009) 293–295.

*****