Design, Development and Evaluation of Biogas Plant using Donkey-dung and Selected Biomaterials as Feedstock

N Kannan, *Non-member*
T Guruswamy, *Fellow*
V Kumar, *Non-member*

An investigation was undertaken in two stages to evaluate the characteristics of three feed materials namely, poultry droppings, parthenium and eucalyptus leaves and to optimise these feed materials with donkey-dung combination for quantity and quality of biogas production. In the first stage of investigation, the prototype digesters of 75 litre capacity of three different height to diameter ratios of 1:0.5, 1:1 and 1:1.7 were fabricated and fed with above feed materials in 3:1 proportion (donkey-dung: substrate) and compared with 100% donkey-dung as control for a retention period of 56 days under batch fed system. The results indicated that, poultry droppings and donkey-dung combination produced a total gas production of 400.61 l, 350.99 l and 320.35 l, in 1:1.7, 1:1, and 1:0.5 size (H/D ratio) digesters, respectively. While, a total gas production of 242.57 l, 232.68 l and 216.39 l in parthenium and donkey-dung combination and 242.57 l, 232.68 l and 216.39 l in eucalyptus leaves and donkey-dung combination were recorded in 1:1.7, 1:1 and 1:0.5 size (H/D ratio) digesters, respectively. In case of control treatment of 100% donkey-dung these values were 261.11 l, 244.47 l and 233.10 l respectively. The average methane content in the biogas produced from poultry droppings and donkey-dung combination were 58.13%, 49.61% and 54.28% in 1:0.5, 1:1 and 1:1.7 size (H/D ratio) digesters, respectively. The corresponding values in the biogas produced from parthenium and donkey dung combination were 43.95%, 43.35% and 44.88% and in eucalyptus and donkey-dung combination, these values were 43.60%, 48.70% and 51.69%, respectively. In the second stage of investigation, a pilot size floating drum type biogas plant of 0.5 m^3 capacity was designed, developed and evaluated for optimised feedstock of poultry droppings and donkey-dung combination in 3:1 proportion for quantity and quality of biogas production for retention period of 7 weeks. The results revealed that, a total gas production of 9341.2 l with average methane content of 61.52% was recorded at the end of retention period, Nitrogen, phosphorous and potassium values of 2.43%, 0.85% and 0.72% were recorded in the digested slurry during 42 days of retention period.

Keywords: Poultry droppings; Parthenium; Eucalyptus; Biogas plant

NOTATION

BD	:	bulk density of charge, kg/m^3
D	:	inside diamter of the digester, m
h_1	:	height of cylindrical portion of gas holder, m
h_2	:	height of conical portion of gas holder, m
H	:	height (depth) of the digester, m
HRT	:	hydraulic retention period, days
r_1	:	inside radius of gas holder, m
V_C	:	volume of daily charge, m^3
V_{Ci}	:	volume of cylindrical portion of gas holder, m^3
V_{Co}	:	volume of conical portion of gas holder, m^3
V_D	:	digester volume, m^3
V_T	:	total volume of gas holder, m^3
W	:	weight of (dung + water), kg

N Kanan, T Guruswamy and V Kumar are with college of Agricultural Engineering, Raichur.

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INTRODUCTION

Energy is one of the prerequisites for the growth of agriculture and industry. The energy requirements are met mainly through commercial energy sources like oil, natural gas etc. In recent years, the prices of these commercial energy sources have increased sharply and there is a continuous depletion of these scarce resources. Hence, there is an urgent need to develop and exploit the alternate sources of energy. Biogas is one of the good and promising sources of alternate energy. This energy can be harnessed successfully to meet the existing as well as future needs of the rural areas. Biogas is the fourth largest source of energy in the world supplying about 13 % (55 EJ/yr), which is equivalent to 25 million barrels of primary energy (Mittal, 1997). India has the largest population of livestock of over 300 million, which produce about 980 million tonnes of cattle dung. If the entire quantity of available dung is used for biomethanation, it could generate nearly 70.22 GJ of energy annually[1]. Nearly 70% of Indian farmers own 2 animals to 3 animals per household. If this category of farmers intend to own a biogas plant, the required quantity of dung transfer can not be met on their own farmsteads. To meet this demand, there is a need to search for an alternate feedstock as supplement to cattle dung. The commonly grown

weeds on the farm and crop residues, which are not suitable for cattle feed are generally left in the field as waste or burnt in the field itself. The biomass from such wastes could produce energy equivalent to 15 kJ/g through combustion. However, if the same is used for biomethanation process, it could produce nearly 150 kJ/g of energy[2].

Hill[3] conducted an experiment on anaerobic digestion of poultry droppings at 35°C for a retention period of 30 days and reported that the gas production was 0.36 m^3/kg of volatile solids added. Gunaseelan[4] conducted studies on biogas production using parthenium as an additive with cattle dung at 10% and reported that the methane content of gas varied from 60% to 70% for a retention period of 8 weeks. In India, there are about 1.5 million donkeys, which constitute about 3.38% of the world's donkey population. Karnataka accounts for 5.2% of donkey population in India. The use of donkeys for field operations like ploughing, harrowing, sowing and inter-cultivation, for operating processing equipments like chaff cutter, groundnut decorticator, maize shellers through rotary mode of operation, pumping water from shallow water table of 2 m to 3 m depth and for hauling steel carts for transportation have been reported (Anonymous, 1996). While the information on utility of donkeys for other purposes have been not reported.

Hence, there is a need to evaluate the utility of donkey-dung as a source for biogas production. The information on use of donkey-dung for biogas production either alone or in combination with other substrates is not available in Northern Karnataka. Keeping the above facts in view, the present study was undertaken to develop and evaluate a biogas plant using donkey-dung and selected biomaterials as feedstock.

MATERIAL AND METHODS

Selection of Feed Materials

The feed stock materials namely, donkey-dung, poultry droppings, parthenium and eucalyptus leaves were selected and their performance was evaluated in three different sized digesters of 1:0.5, 1:1 and 1:1.7 H/D ratio as suggested by Acharya[5] to optimize these feed stocks with donkey-dung combination for quantity and quality of biogas production at 3:1 proportion for a retention period of 56 days under batch fed system.

Treatments

The different treatments selected for the study are given in Table 1.

The above three feed materials namely, poultry droppings, parthenium and eucalyptus leaves were mixed with donkey-dung in 3:1 proportion, *ie*, three parts of donkey-dung and one part of substrate on wet basis. The feed material combination used in this study are as under:

1. 75% donkey-dung + 25% poultry droppings
2. 75% donkey-dung + 25% parthenium
3. 75% donkey-dung + 25% eucalyptus leaves
4. 100% donkey-dung (control)

Table 1 Details of different treatments in 3:1 (donkey-dung : substrate) proportion.

S No	Treatment	H/D ratio
1	Donkey-dung + Parthenium	1.0:0.5
2	Donkey-dung + Parthenium	1.0:1.0
3	Donkey-dung + Parthenium	1.0:1.7
4	Donkey-dung + Eucalyptus leaves	1.0:0.5
5	Donkey-dung + Eucalyptus leaves	1.0:1.0
6	Donkey-dung + Eucalyptus leaves	1.0:1.7
7	Donkey-dung + Poultry droppings	1.0:0.5
8	Donkey-dung + Poultry droppings	1.0:1.0
9	Dunkey dung + Poultry droppings	1.0:1.7
10	Control (100% Donkey-dung)	1.0:0.5
11	Control (100% Donkey-dung)	1.0:1.0
12	Control (100% Donkey-dung)	1.0:1.7

Fabrication of Prototype Digesters

A cylindrical shaped 75 l capacity digester was chosen for feeding each substrate with donkey-dung in 3:1 proportion and 100% donkey-dung as control. The dimensions of digesters namely, height and diameter were determined using standard formula. Twelve prototype digesters were fabricated according to the design dimensions as explained here.

As per the calculated dimensions, a MS sheet of 18 gauge was cut and folded into a cylindrical shape using a hand operated sheet bending machine A 65 mm diameter hole was drilled at the top of the drum for feeding the feed material and a suitable GI collar was fitted. Another hole of 6.2 mm diameter was drilled to fix an outlet pipe in order to draw the gas. A suitable GI bend was fixed at the outlet of the digester with a control valve for regulating gas.

Charging of Prototype Digesters

Initially, an inoculum of about 25 ml of biogas spent slurry was added to the substrates in all the three digesters to initiate biogas production. The substrates prepared in the above proportion were filled in the digesters and kept outside the laboratory for biogas production for a retention period of 56 days.

Physico-chemical Properties

The different physico-chemical properties like moisture content, total solids, volatile solids, bulk density, pH, carbon content, nitrogen content of feed materials before and after digestion were analysed using standard procedures.

Quantity and Quality of Gas

The volume of gas produced in each prototype digester was measured using a wet type gas flow meter. Initially, the gas flow meter was filled with distilled water to the indicated level. A 6.2 mm diameter pipe was connected to draw the gas

from prototype digester to gas flow meter. The amount of gas produced in 24 h was measured daily from all the digesters up to 56 day.

The percentage of methane content and carbondioxide in the biogas produced under different treatments was measured using Orsat apparatus. The procedure used for quality analysis of gas is explained below:

The gas produced from the prototype digesters was filled in the bladder (balloon). Then the bladder was connected to the main tube of the Orsat apparatus. Initially, all the four knobs provided in the apparatus tubes were closed. Afterwards, the three way knob provided for entry of gas was opened and the gas was allowed to enter the main tube and then into the graduated burette. After setting to zero, the knob provided to the tube filled with 2% boric acid was opened and the bottle was moved up and down for about 10 times to 12 times so that the water pushed the gas into the tube and agitated properly. During this process, the boric acid absorbed the ammonical nitrogen content present in the biogas generated. Again, the bottle was placed to its original position and the rise in the water level in the burette was recorded. This rise indicated the amount of ammonia present in the biogas. Similar procedure was followed by opening the knob of NaOH (10%) tube and noting the rise in the water level that gave the amount of carbondioxide preset in the sample collected in the bladder. The remaining empty space above the water level after completion of the above two processes gave the methane content of biogas.

The feed stock combination which gave the optimum biogas production with better quality of biogas was identified and evaluated for quantity and quality of biogas generation in 0.5 m^3 capacity floating drum type biogas plant.

DESIGN OF PILOT SIZE BIOGAS PLANT

The 0.5 m^3 capacity floating drum type biogas was designed to meet the cooking requirement of a family consisting of two adults and one child. According to Rai[6] the gas requirement for cooking per adult per day is 0.22 m^3. Hence, the gas requirement per day for the above said family worked out to be $0.22 \times 2 + 0.11 = 0.55$ m^3/day. It was assumed that a single donkey and a single poultry bird could produce about 10 kg dung and 0.18 kg poultry litter per day, respectively, (Rai[6]). For generating 0.5 m^3 gas per day, a pair of donkeys and 20 poultry birds were considered. In order to make donkey-dung and poultry droppings combination in 3:1 proportion, 11.4 kg of donkey-dung and 3.8 kg of poultry droppings were mixed for feeding the biogas plant daily to produce 0.5 m^3 gas. The hydraulic retention period of 42 days was considered.

Digester

The size of the digester was calculated using the following formula:

$$V_D = V_C \times \mathrm{HRT} \quad (1)$$

$$V_C = \frac{W}{BD} \quad (2)$$

The height of digester was calculated using the following formula:

$$V_D = \frac{\pi}{4} \times D^2 \times H \quad (3)$$

Gas Holder

Most of the floating drum type biogas plants have cylindrical shaped gas holder (Rai[6]). Accordingly, cylindrical shaped drum with conical dome was selected as gas holder for collecting the gas. The gas holder was designed for 75% of volume required for daily gas production. Hence, the volume of the gas to be collected by the gas holder worked out to be as $0.5 \times 0.75 = 0.375$ m^3/day. A clearance of 7.5 cm was provided on both the sides of gas holder as well as lifting of gas lifting of gas holder whenever desired.

The total volume of the gas holder, was calculated using the following formula.

$$V_T = V_{Ci} \times V_{Co} \quad (4)$$

where

$$V_{Ci} = \pi \times r_1^2 \times h_1$$

and

$$V_{Co} = 1/3 \times \pi \times r_1^2 \times h_1$$

CONSTRUCTION OF BIOGAS PLANT

The site selected for conducting field study was non-rocky area with very low water table. The soil was deep black soil which mainly consisted of montmorillinite clay which shrinks during summer when dried and swells during rainy season. Because of these properties, the digester constructed with bricks is likely to crack and reduce the life span of the plant. To overcome these problems, pre-cast ferro-cement rings were used for construction of digester well.

Digester

Initially the ground was cleaned and made free of weeds, stones, etc. A circle of 1.8 m diameter was marked on the ground using lime powder. The soil was dug up to a depth of 2.2 m till the hard pan of soil was noticed. A 15 cm thick cement concrete bed using 1:3.6 proportion was laid out. Seven pre-cast ferro-cement concrete rings of 1.2 m diameter and 6.3 m height were placed one over the other on the prepared concrete bed. The gap between the rings was sealed properly using 1:6 cement mortar. A pre-cast cement pipe of 10 cm diameter and 3 m length was inserted in the digester at 45° as inlet pipe at a height of 45 cm from the bottom of the digester.

Inlet Tank

A cylindrical shaped tank was constructed using ferro-cement concrete rings as inlet tank. A 60 cm diameter circle was marked on the ground and the soil was dug up to a depth of 30 cm. Five pre-cast ferro-cement concrete rings of 45 cm diameter and 30 cm height were placed one over other. Inlet pipe was installed at 65 cm height from the ground level.

Outlet Tank

An empty drum of 170 l (50 cm diameter and 85 cm height) coated with asphalt was selected for outlet and erected at 30 cm distance from the digester well. Initially, a circle of 75 cm diameter was marked and the soil was dug up to one meter and the bottom portion was filled with coarse murrum to a thickness of 15 cm. Two holes of 5 cm diameter were drilled at one side of the drum. To these holes, two pre-cast cement pipes of 5 cm diameter and 30 cm length were fixed at a height of 35 cm and 65 cm from the bottom of the outlet tank, respectively for collecting the digested slurry for retention period of 28 days and 35 days, respectively. An outlet pipe of 5 cm diameter and 30 cm length was installed at 12 cm above the outlet tank for collection of slurry at the end of 42 days of retention period.

Gas Holder

A cylindrical drum with a conical shaped dome was selected for gas holder. A 18 gauge MS sheet of 1.2 m width and 3 m length was cut and folded into cylindrical shape using hand operated sheet bending machine and welded carefully. MS sheet of 18 gauge was cut for making conical shaped dome having base of 1.2 m diameter. An arc of 35 cm length was cut from this sheet. The remaining portion of the circle was bent into conical shape and welded and this conical portion was placed over cylindrical portion of the gas holder and welded. At the centre, a pipe of 3 cm diameter and 60 cm length was welded inside the gas holder to act as guiding pipe. A 2.5 cm diameter hole was drilled at the upper side of the drum to which a 2.5 cm diameter bend and a PVC control valve of 2.5 cm diameter were fixed or regulating the flow of gas.

Charging the Digester

The donkey-dung and poultry droppings were mixed in 3:1 proportion (75% donkey-dung and 25% poultry droppings) on weight basis. Initially, the digester was filled with this combination up to 75% of its volume. In order to achieve this level, 337 kg of donkey-dung and 112 kg of poultry droppings were collected and mixed thoroughly by adding 1417 l mixed of water for maintaining the total solids in the slurry up to 10%. The digester was charged by adding inoculum of 6% of digester volume in the form of digested slurry. The calculated quantity of slurry (donkey-dung and poultry droppings in 3:1 proportion) was fed into the digester, daily for a retention period of 42 days. The gas started generating from third week.

Quantity and Quality of Gas

The quantity and quality of gas generated were measured using standard procedure as explained earlier.

Quality Analysis of Digested Slurry

The total nitrogen content of the digested slurry was analysed using Microkjeldhal method as suggested by Mahimairaja[7], *et al*. The phosphorous and potassium contents of the digested slurry were analysed using standard procedure as suggested by Jackson[8]. In order to optimise the retention period, three retention times of 28 days, 35 days and 42 days were considered to analyse the quality of digested slurry.

RESULTS AND DISCUSSION

Performance of Feed Materials in Prototype Digesters

The results pertaining to the performance of three feedback materials namely, poultry droppings, parthenium and eucalyptus leaves in combination with donkey-dung in 3:1 proportion in three different sized prototype digesters are presented below.

Physico-chemical Properties

The different physico-chemical properties of feed materials before digestion are presented in Table 2.

From the Table 2, it was observed that poultry droppings has got higher nitrogen content (5.9%) and favourable pH (7.01) as compared parthenium (3.1% N and 6.8 pH) eucalyptus leaves (2.39% N and 4.57 pH).

The different physico-chemical properties of feed materials after digestion are presented in Table 3.

It was observed that the poultry droppings and donkey-dung combination showed optimum total solids content of 8.5% which is suitable for biogas production.

Table 2 Physico-chemical properties of feed materials before digestion

Feed Material	Physical Properties				Chemical Properties			
	MC, %	TS, %	VS, %	BD, %	pH	C, %	N, %	CN Ratio
Poultry droppings	65.25	34.75	76.26	695.6	7.01	45.20	5.90	7.93
Parthenium	83.55	16.45	72.69	573.3	6.83	33.30	3.10	10.74
Eucalyptus leaves	52.30	47.70	85.63	617.4	4.57	55.30	2.39	23.14
Donkey-dung	51.55	48.45	72.14	896.5	6.97	48.30	1.85	26.11

Table 3 Physico-chemical properties of different feed materials combination after digestion

Feed Material Combination	Physical Properties			Chemical Properties		
	TS, %	VS, %	pH	C,%	N,%	CN Ratio
Donkey-dung + Poultry droppings	8.50	62.20	5.54	32.87	2.46	13.36
Donkey-dung + Parthenium	14.40	64.30	5.93	37.86	2.21	17.13
Donkey-dung + Eucalyptus leaves	16.70	67.90	5.15	43.04	2.14	20.11
Donkey-dung alone	8.10	63.50	5.78	35.06	2.05	17.10

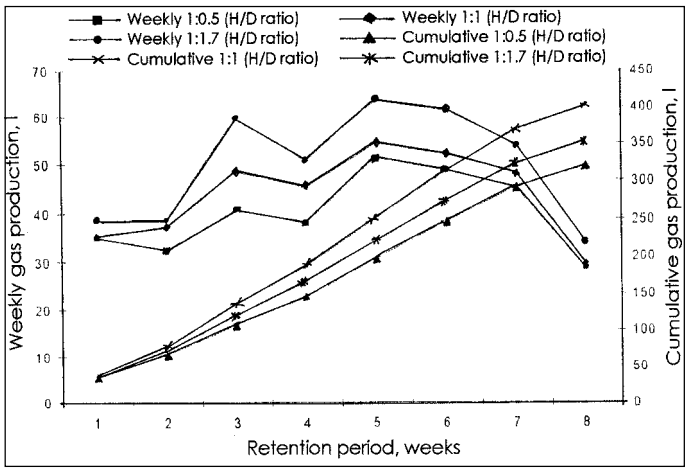

Figure 1 Weekly and cumulative gas production from poultry droppings and donkey-dung combination in three diffrent size (H/D ratio) digesters

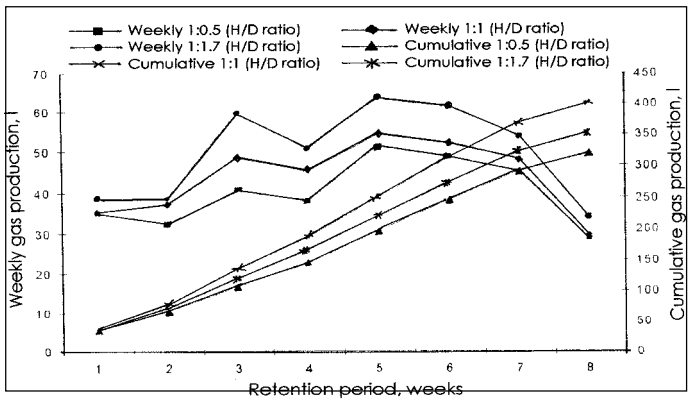

Figure 2 Weekly and cumulative gas production from parthenium and donkey-dung combination in three diffrent size (H/D ratio) digesters

Quantity of Biogas

The results of weekly and cumulative gas production from poultry droppings and donkey-dung combination in three different sized digesters is presented in Figure 1.

It was observed that the cumulative gas production was maximum (400.61 l) in 1:1.7 H/D ratio digester followed by 1:1 size digester (350.99 l) and 1:0.5 size digester (320.35 l) at the end of retention period of 56 days. This may be due to relatively lower pressure acting on the microbes. The weekly gas production fluctuated maximum from first to fifth week and thereafter it decreased gradually till the retention period of 8 weeks in all the three digesters.

The results of weekly and cumulative gas production from parthenium and donkey-dung combination in three different sized digesters are presented in Figure 2.

A maximum cumulative gas production of 242.57 l was observed in 1:1.7 H/D ratio digester followed by 1:1 size digester (232.68 l) and 1:0.5 size digester (216.39 l) at the end of retention period of 56 days. This may be due to relatively lower pressure acting on the microbes by larger diameter digester. The weekly gas production tended to increase up to fifth week and thereafter it decreased gradually till the retention period of 8 weeks in all the three digesters.

The results of weekly and cumulative gas production from eucalyptus and donkey-dung combination in three different sized digesters are presented in Figure 3.

It was observed that 1:1.7 H/D ratio recorded the maximum cumulative gas production (254.61 l) followed by 1.1 size digester (230.71 l) and 1:.05 size digester (217.96 l) at the end of retention period of 56 days. The low pressure acted upon the microbes in 1:1.7 sized digester led to higher gas production. It was observed that the weekly gas production tended to increase up to fourth week and thereafter it decreased till the end of retention period of 8 weeks in all the three digesters.

The results of weekly and cumulative gas production from donkey-dung alone in three different sized digesters are presented in Figure 4.

A maximum cumulative gas production of 261.11 l was recorded in 1:1.7 H/D ratio digester followed by 1:1 size digester (244.47 l) and 1:0.5 size digester (233.10 l) at the end of retention period of 56 days. The weekly gas production fluctuated marginally from first to fifth week and thereafter it decreased gradually till the retention period of 8 weeks in all the three digesters.

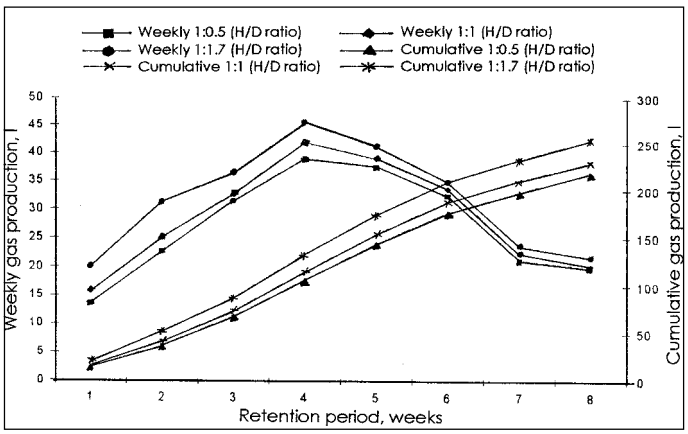

Figure 3 Weekly and cumulative gas production from eucalyptus leaves and donkey-dung combination in three diffrent size (H/D ratio) digesters

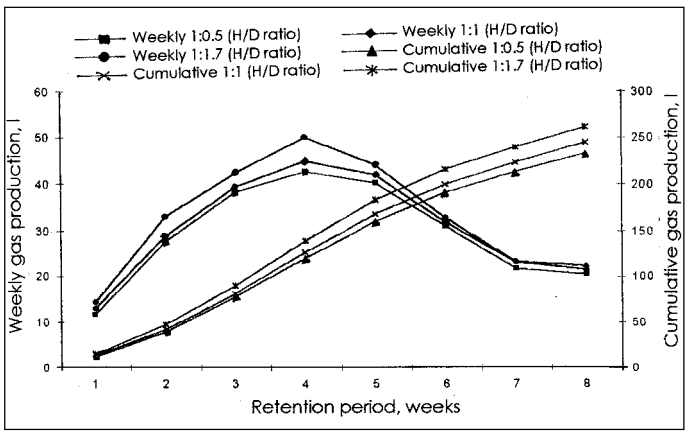

Figure 4 Weekly and cumulative gas production from donkey-dung alone (control) in three diffrent size (H/D ratio) digesters

Among three feedstocks in three different sized digesters, the combination of poultry droppings and donkey-dung in 3:1 proportion gave maximum gas production (400.61 l) compared to other two feedstock combinations, *ie,* parthenium and donkey-dung combination (242.57) and eucalyptus leaves and donkey-dung combination (254.61). This may be due to higher nitrogen content (5.9%) and favourable pH of 7.01 in poultry droppings as compared to other two feedstock namely, parthenium (3.1% N and 6.8 pH) and eucalyptus leaves (2.39% N and 4.57pH) as given in Table 2.

Quality of Biogas

The percentage of methane content in the gas generated increased gradually from first week to sixth and thereafter it decreased gradually till the retention period of 8 weeks. This trend was observed in all the three substrates and in the control treatment of donkey-dung alone. The average methane content of 58.13%, 49.61% and 54.28% were recorded in the gas generated from poultry droppings and donkey dung combination in 1:0.5, 1:1 and 1:1.7 sized digesters, respectively for the entire period of 56 days. In case of parthenium and donkey-dung combination, the average methane contents of 43.95%, 43.35% and 44.88% were recorded, while in the gas produced from eucalyptus leaves and donkey-dung combination these values were 43.60%, 48.70% and 51.69%, respectively in 1:0.5, 1:1 an 1:1.7 sized digesters for the entire period of 8 weeks. An average methane content of 47.44%, 46.21% and 47.78% were recorded in the gas generated from donkey-dung alone in 1:0.5, 1:1 and 1:1.7 sized digesters, respectively.

The analysis of gas production indicated that, the average methane content was maximum in poultry droppings and donkey-dung combination over other feedstock combination. This may be due to the optimum total solids of 8.5% in poultry droppings and donkey dung combination (Table 3).

PERFORMANCE OF PILOT SIZE BIOGAS PLANT

The results pertaining to the performance of poultry droppings and donkey-dung combination at 3:1 proportion in pilot size biogas plant are presented below.

Quantity of Biogas

The results of weekly and cumulative gas produced from poultry droppings and donkey dung combination in 0.5m^3 capacity floating drum type biogas plant are presented in Figure 5.

It was observed that, a maximum of 2443.6 l of gas was produced during fifth week of retention period followed by fourth week (2400 l), sixth week (2397.4 l) and a minimum of 2011.4 l during the seventh week. The results indicated that the gas production increased gradually up to fifth week and thereafter it decreased gradually till the end of retention period of 42 days.

Table 4 Gas constituents of biogas produced in biogas plant

Gas Constituent, %	Retention Period, Week				
	III	IV	V	VI	VII
Methane	52.5	59.4	62.6	64.5	68.6
Carbon dioxide	42.4	35.2	31.8	29.4	25.0
Other gases	5.1	5.4	5.6	6.1	6.4

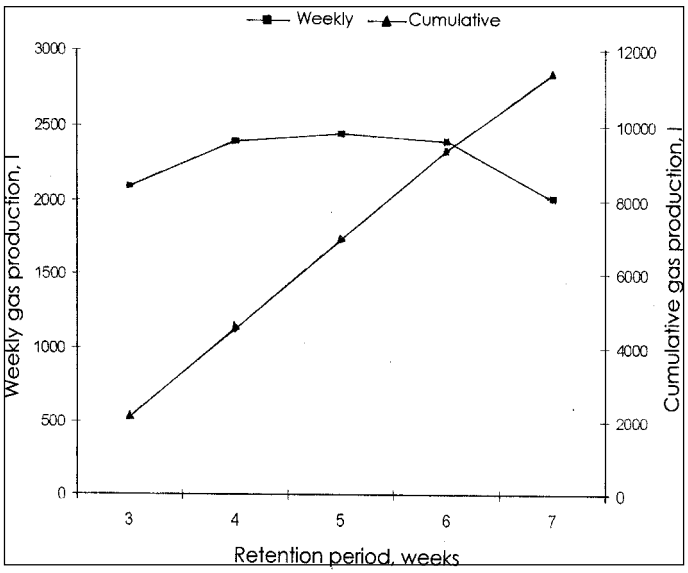

Figure 5 Weekly and cumulative gas production from poultry droppings and donkey-dung combination in pilot size biogas plant

Table 5 Nutrient composition of digested slurry

Retention Period Days	Nitrogen (N), %	Phosphorus (P), %	Potassium (K), %
28	2.40	0.84	0.69
35	2.42	0.84	0.70
42	2.43	0.85	0.72

Quality of Biogas

Gas constituents of biogas produced from poultry droppings and donkey-dung combination in biogas plant are presented in Table 4.

The results indicated that, the percentage of methane content in the gas generated varied from 52.5% to 68.6% the methane content tended to increase gradually from first week to seventh week and it was maximum (68.6%) during seventh week. While the percentage of carbondioxide in the gas was in the reverse proportion to that of methane gas.

Quality Analalysis of Digested Slurry

The nutrient composition of digested slurry which includes N, P and K valus for three retention periods of 28 days, 35 days and 42 days is presente in Table 5.

The percentage of nitrogen (N), phosphorus (P) and potassium (K) varied from 2.4% to 2.43%, 0.84% to 0.85% and 0.69% to 0.72%, respectively. The maximum percentage during 42nd day of retention period followed by 35th day (2.42% N, 0.84%

P and 0.70% K) and a minimum of 2.40%, 0.84% and 0.69%, respectively during 28th day of retention period.

CONCLUSIONS

- In case of poultry droppings and donkey-dung combination, the cumulative gas production was maximum (400.61 l) in 1:1.7 size (H/D ratio) digester followed by 1:1 size (H/D ratio) digester (350.99 l) and 1:0.5 size (H/D ratio) digester (320.35 l), while in case of parthenium and donkey-dung combination these values were 242.57 l, 232.68 l and 216.39 l, in case of eucalyptus leaves and donkey-dung combination these values were 254.61 l, 230.71 l and 217.96 l, respectively and in control treatment of donkey-dung alone these were 261.11 l, 244.47 l and 233.10 l, respectively.
- The maximum average methane contents of 58.13%, 49.61% and 54.28% were recorded in the gas generated from poultry droppings and donkey-dung combination over other two feedstock combination namely, parthenium and donkey-dung combination (43.95%, 43.35% and 44.88% and eucalyptus leaves and donkey-dung combination (43.60%, 48.70 and 51.69) in 1:0.5, 1:1 and 1:1.7 size (H/D ratio) digester, respectively.
- Poultry droppings as a partial substrate with donkey-dung combination as feed material is found to be superior in terms of quantity and quality of gas production over other two substrates namely, parthenium and eucalyptus leaves with donkey-dung combination.
- Among the three digesters, 1:1.7 size (H/D ratio) digester performed better compared to 1:0.5, 1:1 size (H/D ratio) digesters in terms of quantity of gas generated for retention period of 56 days.
- In 0.5 m^3 capacity floating drum type biogas plant, poultry dropping and donkey dung combination produced a maximum of 2443.6 l of gas during fifth week retention period followed by forth week (2400 l), sixth week (2397.4 l) and a minimum of 2011.4 l during seventh week of retention period.
- The percentage of methane content in the gas produced from poultry droppings and donkey-dung combination in pilot size biogas plant varied from 52.5% to 68.6% with a maximum of 68.6% during seventh week of retention period.
- The percentage of nitrogen (N), phosphorous (P) and potassium (K) in the digested slurry of poultry droppings and donkey-dung combination varied from 2.40% to 2.43%, 0.84% to 0.85% and 0.69% to 0.72%, respectively.
- The maximum percentage of nitrogen (2.43%), phosphorous (0.85%) and potassium (0.72%) were recorded during 42nd day of retention period followed by 35th day (2.42% N, 0.84% P and 0.70% K) and a minimum of 2.40%, 0.84% and 0.69%, respectively, during 28th day of retention period.
- Finally, poultry droppings and donkey-dung combination as feed material can generate on an average a total gas of 11352 l with an average methane content of 61.52% 0.5 m^3 floating drum type biogas plant yielding digested slurry, which contains an average of 2.42%, 0.84% and 0.70% of nitrogen, phosphorous and potassium, respectively.

REFERENCES

1. G P Govil and R R Gaur. 'Development of Conversion Kits to Promote the use of Biogas in Existing Diesel Engines for Variable Load Rural Applications.' *Proceedings of National Conference on Commercialization Aspects of Renewable Energy Sources,* 2000, p 100.

2. A W Khan, S S Miller and W D Murry. 'Development of a Two Phase Combination Fermenter for Conversion of Cellulose to Methane.' *Biotechnology Bioengineering,* 1983, vol 25, p 1571.

3. D T Hill. 'Methane Productivity of the Major Animal Waste Types.' *Transactions of American Society of Agricultural Engineers,* 1984, vol 27, p 530.

4. V N Gunaseelan. 'Parthenium as an Additive with Cattle Manure in Biogas in Production.' *Biological Wastes*, vol 21, 1987, p 195.

5. C N Acharya. 'Preparation of Fuel Gas and Manure by Anaerobic Fermentation of Organic Materials.' *ICAR Research Series Bulletin,* no 15, 1958, p 10.

6. G D Rai. 'Non-conventional Sources of Energy.' *Khanna Publishers,* New Delhi, 1999, p 140.

7. S Mahimairaja, N S Bolan, M J Hedley and A N MacGregor. 'Evaluation Methods of Measurements of Nitrogen in Poultry and Animal Manure.' *Fertilizer Resources,* vol 24, 1990, p 141.

8. M L Jackson. 'Soil Chemical Analysis.' *Prentice Hall of India Pvt Ltd,* New Delhi, 1967, p 498.

9. K M Mittal. 'Conventional Energy Systems, Principles, Progress and Prospects.' *Wheeler Publishing Company,* New Delhi, 1997, p 120.

10. 'Year Book of Statistics.' *Food and Agricultural Organization,* 1992, vol 46, p 105.

11. 'Utilization of Animal Energy with Enhanced System Efficiency.' *Research Digest of AICRP, University of Agricultural Sciences, Dharwad,* Raichur Centre, 1996, p 30.