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Biogas Generation via Anaerobic Digestion on the Influence of Different Parameters and Used as Secondary Fuel for CI Engine

K.Senthilkumar and S.Vivekanandan
Annamalai University, Annamalai Nagar, Tamilnadu,India.

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ABSTRACT
The aim of this study was to optimise the biogas generation from anaerobic digestion process and to investigate the biogas as secondary fuel for the CI engine. The parameters studied were total solid concentration (TS), initial pH and co digestion of slurry. The effectiveness of animal and industrial waste was investigated using 1 m3 bio digester working in a continuous process. Anaerobic digestion seemed feasible with loading rate of 8%,10% and 12% (TS)and biogas yield reported as 82.3m3,110.9m3 and 74.4 m3 respectively. The data obtained establish the importance of pre-treatment and total solids for achieving higher cumulative biogas yield. The volume of generated biogas was effectively used as secondary fuel for an engine by modifying the engine inlet manifold to operate with dual fuel mode.

Introduction

Anaerobic digestion is a biological process converts the complex organic matter in to simple products in the absence of oxygen by a group of micro organism results in rich biogas yield, mixture of methane and carbon dioxide which can be used as renewable energy resources [1]. Among the various energy resources biogas conversion technology appear to be the simple and best suited for many domestic applications and also used for conversion of energy to shaft power as a secondary fuel.

Biogas is produced by anaerobic digestion of biodegradable material such as manure, crop residue and industrial residues [2]. The yield of biogas from any organic substrate highly depends on total solid concentration of the slurry, pH, temperature, carbon to nitrogen ratio [3]. The inoculums effect of different feed stock is among the main parameters influencing the biogas production [4].

In this study the effect of inoculums of animal manure-cow dung as co- substrate with cane industrial residue - press mud was the subject of this investigation [5]. It is observed due to the synergistic effect in the co digestion process, the biogas/methane yield will be more as compared to single digestion [6]. This study was conducted with various total solids concentration of these wastes influence the amount of biogas yield was studied in order to determine the conditions for optimum gas generation [7]. The biogas produced from the plant was purified and upgraded is fed to the engine inlet manifold, mixed with air by slight modification in the manifold of the engine and to evaluate the engine running with biogas-diesel as dual fuelled mode.

Experimental materials and methods

The experiment was conducted in the Department of Mechanical Engineering, Annamalai university. The anaerobic floating drum type bio digester with a plant capacity of $1m^3$ made up of fibre material and gas holding floating dome of 700 litres [8].

The raw material cow dung is taken from rural area near Chidambaram town and press mud taken from nearby sugar cane industry [9]. Both the feeds are dried one week in sunlight and crushed mechanically [10]. The dried cow dung used as an inoculums / co substrate in the range 7 to 7.5 by mixing waste/water around 1:2 ratio and charged the digester [11]. The digester was operated in a continuous process with mesophilic temperature range of between 25°C-35°C. The digester was loaded with waste/volume 30:70 under anaerobic process [12]. The experimental setup is designed in such a way to prevent any leakage of gas generation from the digester. This was achieved by a water jacket surrounded the digester, the gas holding dome float inside the water jacket may prevent 10% of gas leakage reported in other conventional floating dome type[13].

The raw material press mud is a fibrous material and acidic in nature with pH value ranges from 5.5 to 6 needs a pre-treatment with NaoH to adjust the optimum pH range 7 to 7.5[14]. The digester was charged with waste/volume of 30:70 co digestion of cow dung and press mud as 50:50 ratios with three different loading rates [15].

The following materials used in this work the weighing balance is to determine the weight of the waste sample , a pen type pH meter ranges from 5 to 10 with the digital display. Thermocouple and digital thermometer are used to measure the digester slurry temperature. Mixing tank is used for preparing slurry with different substrate concentration [16]. Pneumatic agitator is used to stirrer the digester and SH Aalborg gas flow meter. The schematic view of experimental set up and photographic view are shown in Fig.1 and Fig.2.

Tele:
E-mail address: ksklme@rediffmail.com

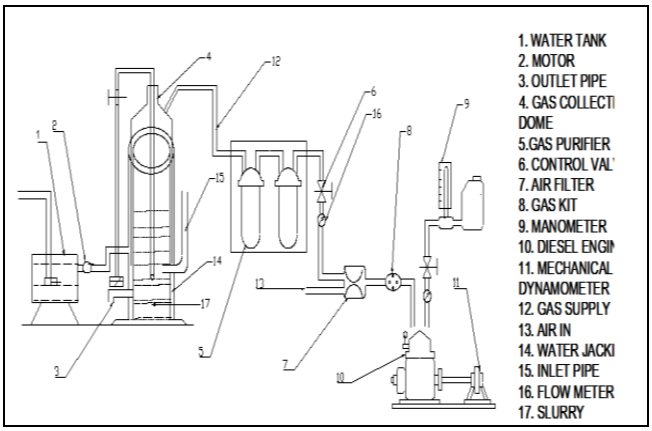

Fig 1. Schematic view of Experimental set up.

Fig 2. Photographic view of Experimental set up.

In this study the experiment was carried out with three total solid concentrations 8%, 10% and 12% respectively. The dry press mud is mixed with 1% NaoH solution dissolved in water. This feed co digested with fermented cow dung for a period of 40 days hydro retention time [17]. The total volume of the digester charged with an effective slurry of 30:70 for all the three feeding concentrations as shown in Table1.

Table 1. Anaerobic co digestion of cow dung/ press mud with different TS%.

Particulars	8% TS	10%TS	12%TS
Waste / volume	30:70	30:70	30:70
Co digestion (cow dung / press mud)	50:50	50:50	50:50
Initial TS %	8%	10%	12%
Initial VS %	4.90%	7.24%	5.68%
Initial pH value	6.4	7.2	8.3
Final pH value	6.0	6.5	7.6
C / N Ratio	29:1	30:1	27:1
Temperature° C	29 to 37	28 to 39	27 to 35
Hydro retention time(HRT) days	40	40	40
Daily biogas production range (litres/day)	16.5 to 20.57	19.75 to 27.80	12.75 to 18.65
Cumulative biogas production (litres/HRT)	82.3	110.9	74.4

The ratio of main component of biogas, CH_4 and CO_2 depends on the composition of feedstock and the property of the anaerobic digestion process. Biogas also contains traces of other gases like H_2, N_2 and H_2S [18]. The properties of biogas and diesel are shown in Table 2.

Table 2. Properties of Biogas and Diesel.

Property and measurement units	Methane (CH_4)	Biogas (60% CH_4 + 40% CO_2)	Diesel (HC)
Theoretical content	55- 70	100	-
Actual content	61- 73	-	-
Calorific value (MJ/M^3)	37.7	22.6	45
Flash point(°C)	650-750	650-750	52-96
Lower explosive limits (%)	5-15	6-12	0.6-7.5
Density (kg/m^3)	0.72	1.2	0.830
Critical temperature(°C)	-82.5	-82.5	-
Critical pressure(Mpa)	4.6	7.3-8.9	-

Experimental analysis

It has been observed that waste/volume of 30:70 loading rate with10% of total solids content in an $1m^3$ bio - digester approximately biogas yield 6.5kw/hr m^3 where as it was reported 0.5kg of diesel may equals 12kw/hr kg[19]. Therefore the generated biogas can be used only as secondary fuel with diesel to run CI engine.

The experiment test was conducted in a single cylinder CI engine of 5 kW, water cooled with different ratios of diesel 80%+20%biogas, diesel 60%+40% biogas and diesel alone and at a rated speed of 1500 rpm for engine specification as shown in Table 3. Biogas used as fuel for engine was generated from 1 m^3 capacity of digester is fed to the engine inlet manifold which designed to supply biogas plus air mixed in a single chamber after upgrading the biogas through purification process [20]. The engine test was conducted with 80% diesel + 20% biogas for different load condition and by comparing the engine with diesel alone for the same load conditions as illustrated in graph.

Results and discussion

It can be seen among the various percentage of total solids concentrations of NaoH pre-treated press mud slurry along with the inoculums cow dung shows the maximum biogas generation of 110.9 litres for 40 days HRT for 10% TS this shows there is a balance in habitats i.e. not overloading of feed reported[21]. The synthesis of gas has been started from between 3rd to 7 th day of the slurry loaded inside the biogas chamber for 8%,10% and 12% TS respectively. A cumulative biogas yield reported as 82.3 litres, 110.9 litres and 74.4 litres respectively for 40 days HRT. The daily biogas yield with respect to HRT was shown in Fig.1.

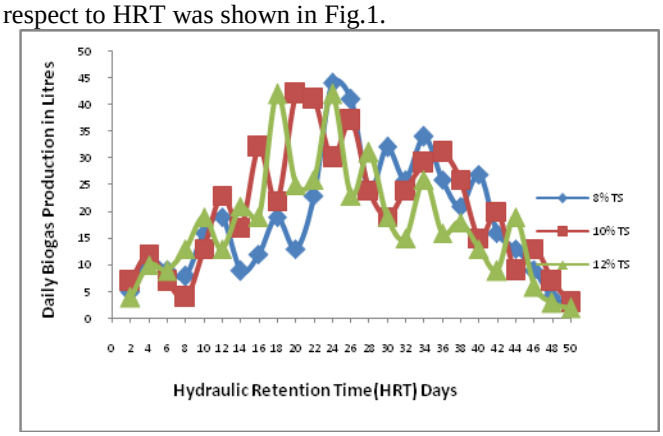

Fig 3. Daily biogas yield Vs HRT days.

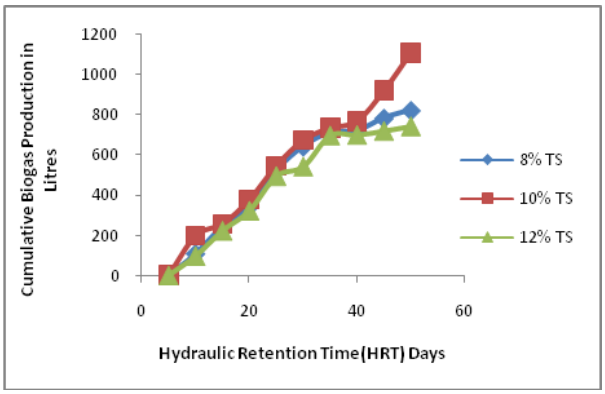

Fig 4. Cumulative biogas yield Vs HRT days.

It was observed that biogas yield from press mud with higher percentage of methane content due to high protein and starch content and for hydro retention time.

It could de deduced from the graphs that generally at 10% TS, the gas production increases steadily than that of 8% and 12% TS as suggested [22]. The figure shows volume of biogas production with respect to number of days under various % TS for daily and cumulative biogas yield load as shown in Fig.1& Fig.4

This study reveals the effect of biogas as secondary fuel for CI engine [23]. To determine the engine performance, load test was conducted at different load conditions running at rated speed for diesel alone, 80% diesel+20% biogas and 60% diesel+40% biogas.

The result suggests that the engine operating with diesel alone shows better thermal efficiency when compare with diesel + biogas as secondary fuel as shown in Fig.5.

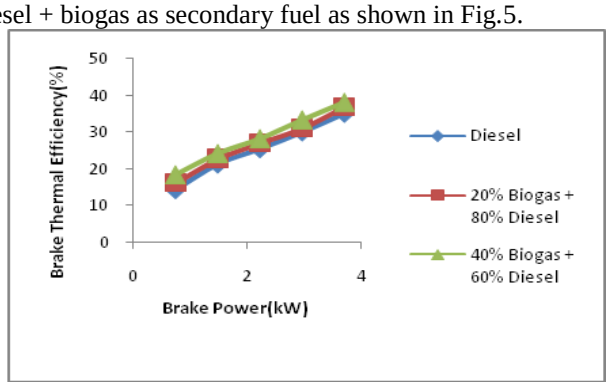

Fig 5. Brake power Vs Brake thermal efficiency.

It is observed when the engine operated at 40% biogas+60% diesel found to be minimum specific fuel consumption as shown in Fig.6.

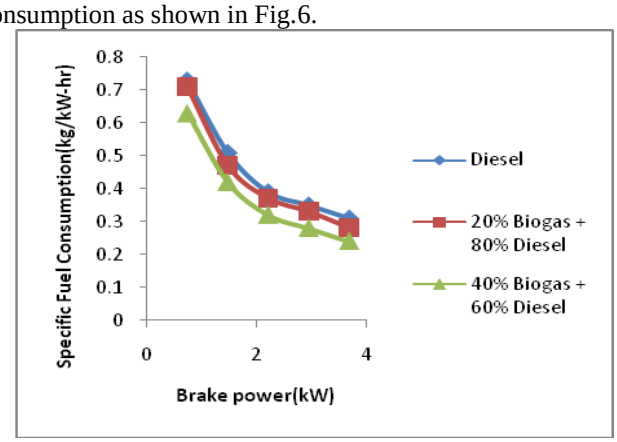

Fig 6. Brake power Vs Specific fuel consumption.

Conclusion

This study reveals that anaerobic digestion can occur with pre-treated press mud organic waste at mesophilic range (<40°C) and a loading rate of 10%TS reported a total biogas production was the highest for a longer retention time.

The addition of inoculums increases the biogas production for all the loading rates. The effect of pre-treated press mud slurry with NaoH solution lead to optimum pH value at the initial loading rate results more biogas yield and quantitatively rich methane content.

Hence biogas yields as 6.5kw/ hr m^3 from $1m^3$ biogas digester but 0.5 kg of diesel which equals 12kw/hr m^3. Therefore the CI engine may only operated with biogas-diesel as a dual fuel at different load condition with rated speed.

Biogas can be used as partial substitution of diesel fuel which may save 40% diesel at different running conditions in the case of 40% diesel+60% biogas.

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