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Bio Gas from Textile Cotton Waste - An Alternate Fuel for Diesel Engines

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Abstract: Methane was generated from cotton waste, while considering its pollution in textile industries. Cotton waste includes solid content and is rich in cellulose having a moisture content of 8.8%. It is difficult to form slurry as the waste float on water and hence an experimental set up has been made like a batch type digester and experiments were conducted with a different proposition of water with or without addition of seeding materials. It was found that cotton waste with 5 to 7.5% seeding material like cow dung or pig dung at temperatures of 30 to 35^{0}C generated bio gas continuously, with a reasonably high yield from the tenth day after feeding. The gas contained rich methane and was tested in a single cylinder diesel engine as a dual fuel had the tendency to save 60% of diesel.

Keywords: Cotton waste, anaerobic digestion, biogas, methane, alternate fuel.

INTRODUCTION

Shortage of conventional liquid fuels and alarming rate of emissions from the internal combustion engines and subsequent environmental pollution have generated interests in the development of new alternatives for petroleum fuels. Bio gas appears to be a promising fuel for cooking, lighting, running vehicles and power generation, etc. It can directly be used in Spark Ignition Engines as an alternate fuel. Although replacing diesel fuel entirely by biogas is very difficult, an increased interest has emerged for the use of biogas, with different amounts and different techniques in diesel engines as a dual fuel operation in recent years [1]. Biogas is produced when certain bacteria decompose biological matter, in an anaerobic environment, known as anaerobic digestion (AD). It is about 20% lighter than atmospheric air and has an ignition temperature in the range of 650^{0}C to 750^{0}C. It is an odorless and colorless gas that burns with clear blue flame similar to that of Liquefied Petroleum Gas and burns with 60% efficiency in a conventional biogas stove [2]. It has a specific gravity of 0.55 in relation to air and its fuel value is directly proportional to the amount of methane [3]. There are different types of bio gas plants such as Khadi, Pragati design, Ganesh Ferro cement digester. These are continuous feeding type digesters using biogas manure, sewage sludge, municipal solid waste, biodegradable waste as feed stock. The basic gas producing reaction in these digesters is $2C+2H_2O=CH_4+CO_2$ [4]. Any material having cellulose as one of its constituents may be used to produce bio gas. India is one of the countries having a large number of textile industries and also having one of the largest cattle populations in the world. The problem of the final scrap from textile industries has now assumed serious dimensions, since it has no salability and pollutes the atmosphere. If these types of waste are not degraded, they get accumulated and occupy space and lead to infectious diseases, attract pests and spread foul odor in the environment. The country consumes cotton fibers approximately 26 million tons per year, of which approximately 0.21 million tons of cotton waste is generated during yarn manufacture. At present this waste is not put into any use except to some extent, as compost for cultivating some vegetables. Mostly, it is disposed off by burning. This may increase the CO_2 level in the atmosphere and also pollutes the surrounding areas. This powder waste also leads to the growth of harmful bacteria, which induce allergic reaction in human. Cotton waste is of high solid powder content and is rich in cellulose. The results for analyses of cotton waste by SITRA (South India Textile Research Association) are given in Table **1**.

Table 1. Contents of Cotton Waste

Contents	Percentage
Moisture	8.80
Ash % by weight	7.20
Ether extractive	12.00
Non-cellulose	16.00
Cellulose	54.00
Nitrogen	0.80
Metals & other	3.20

The technological options for the utilizations of cotton waste at the spinning mills are:

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1. To generate biogas as an additional source of energy and manure and
2. To convert the digested slurry into biomanure by incorporating recycling larva/grubs.

In this work, it was found that five kilograms of cotton waste could generate about 200 liters of biogas in 50 days. It is advantageous for the mills to use their non-salable cotton waste, which is in perennial supply for biogas generation at their premises itself. Normally bio gas is produced either by batch type or continuous type digesters. In this work, batch type digesters are used because the scum is a mixture of coarse fibrous material and it acts as an insulator.

Since cotton waste contains more than 52% of cellulose, high water retention capacity, sufficient carbon-to-nitrogen ratios and low heavy metal content and hence it could be economically converted into biogas and manure. Also, it contains around 70% solid content whereas other raw materials like cow dung which has only 15 to 18%. Cotton waste requires cleaning and some retention time after mixing with water to convert in to slurry, before loading in the digester.

EXPERIMENTAL SETUP

Biogas digester used for this process is a fixed batch type. It consists of a container with a rigidly fixed lid with a provision for gas outlet. It is sealed completely to prevent leakage. The process layout is shown in Fig. (**1**).

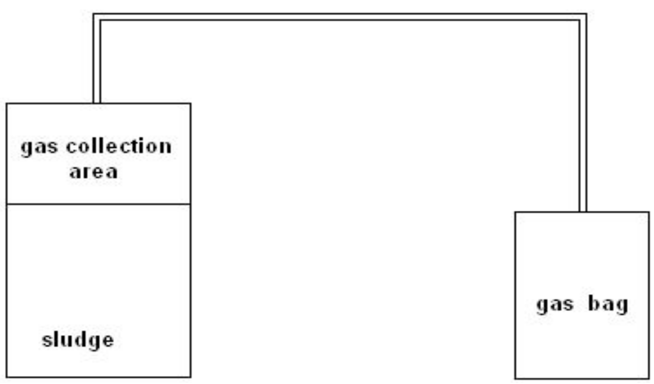


Fig. (1). Layout of bio gas production.

SAMPLE ANALYSIS

Five-kilogram of cotton waste with different seeding material are taken in the specially made digesters as in Fig. (**2**) to generate biogas. Material to water ratio is determined by the nature of the biomass in respect of its moisture content, density, ambient temperature, pH, etc. Excess water may reduce the concentration of biomass in digester and also reduce the volume available for gas collection.

After pre treatment of cotton waste, it is mixed with water in the ratio of 1:2 along with different proportions of seeding material are allowed for fermentation for ten days. Generation of biogas begins from the fifth day and the yield is continuous from the tenth day onwards as the fermentation starts slow in the initial stages and become active after 10 days. It was found that the reaction reduces after 25 days for a stock of 5 kg of cotton waste and nearly comes to an end after 45 days as shown in Table **6** and Fig. (**4**). The anaerobic digestion depends on temperature; as the bacteria (*Mesophile*) is active between 30 to 38^{0}C and thermopile bacteria over 55^{0}C, percentage of seeding material, type of seeding material and percentage of moisture [5].

Fig. (2). Bio gas production setup – Photograph.

Experiments were conducted for 2.5%, 5%, 7.5%, 10% and 15% of seeding material at various temperatures for biogas production. The different seeding materials used are cow dung, pig dung and goat waste. The effect of seed and temperature are represented in Figs. (**3**, **5**) respectively. The outlet gas is tested at CPCL (Chennai Petroleum Corporation Limited) with Gas Chromatography as specified in Table **2** and the values are tabulated from Tables **3-7**.

Table 2. Specifications of Gas Chromatography

Sl.No	Details	Specifications
1	Instrument used	Gas Chromatography, FISONS, Italy
2	Column	Packed
3	Packing material	Porapak Q 80/100
4	Test Conditions	Column temperature: 30^{0}C – 200^{0}C Detector temperature: 150^{0}C Filament temperature: 120^{0}C Detector used: HWD (Hot wise detector) Sample quantity: 0.5 ml Sampling mode: Auto sampler
5	Carrier gas used	Helium

Table 3. Bio Gas Productions Using Cow Dung as Seeding

Sl. No	Constituents	Ratio of Seeding Material (Cow Dung) with Cotton Waste					
		0%	2.5%	5%	7.5%	10%	15%
1	CH_4	25	55	70	77	77.1	77.5
2	CO_2	67	40.85	26.75	19.8	19.57	19.3
3	N_2/Air	8	4.15	3.25	3.20	3.33	3.20

PERFORMANCE EVALUATION IN DIESEL ENGINE

Experiments were conducted on a single cylinder computerized diesel engine test rig with the specifications shown in Table **8**. The bio gas is admitted through a venturi as in Fig. (**6**) and T joint as in Fig. (**7**) at air inlet for proper mixing [6]. The experimental setup is shown in Fig. (**9**) and the results are compared.

Table 4. Bio Gas Production Using Pig Dung as Seeding

Sl. No	Constituents	Ratio of Seeding Material (Pig Dung) with Cotton Waste				
		2.5%	5%	7.5%	10%	15%
1	CH_4	60	72	77.5	77.8	78
2	CO_2	36	24.85	19.3	18.99	19.05
3	N_2/Air	4.00	3.15	3.20	3.31	2.95

Table 5. Bio Gas Production Using Goat Dung as Seeding

Sl. No	Constituents	Ratio of Seeding Material (Goat Dung) with Cotton Waste				
		2.5%	5%	7.5%	10%	15%
1	CH_4	50	65	68	68	68.2
2	CO_2	45.8	31.65	28.7	28.75	28.6
3	N_2/Air	4.2	3.35	3.30	3.25	3.20

Table 6. Bio Gas Production at Different Temperatures for 5% Seeding (Cow Dung)

Sl. No	Constituents	25^0C	27^0C	30^0C	32^0C	35^0C
1	CH_4	52	60.5	77	77.5	78.6
2	CO_2	44.5	36.25	19.8	19.25	18.15
3	N_2/Air	3.5	3.25	3.2	3.25	3.25

Table 7. Bio Gas Production Rate for 5% Seeding (Cow Dung) at Ambient Temperature

Sl. No	Duration	Volume of Gas Collected/5kg of Cotton Waste in Liters
1	5 to 10 days	10
2	11 to 15 days	25
3	16 to 20 days	30
4	21 to 25 days	35
5	26 to 30 days	30
6	31 to 35 days	25
7	36 to 40 days	22
8	41 to 45 days	10
9	46 to 50 days	8

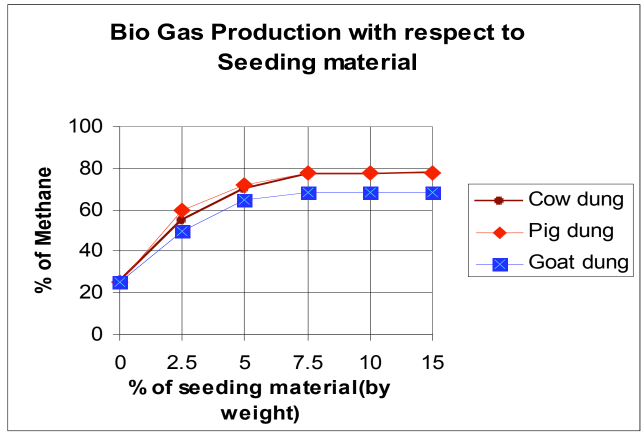


Fig. (3). Effect of gas production with seeding.

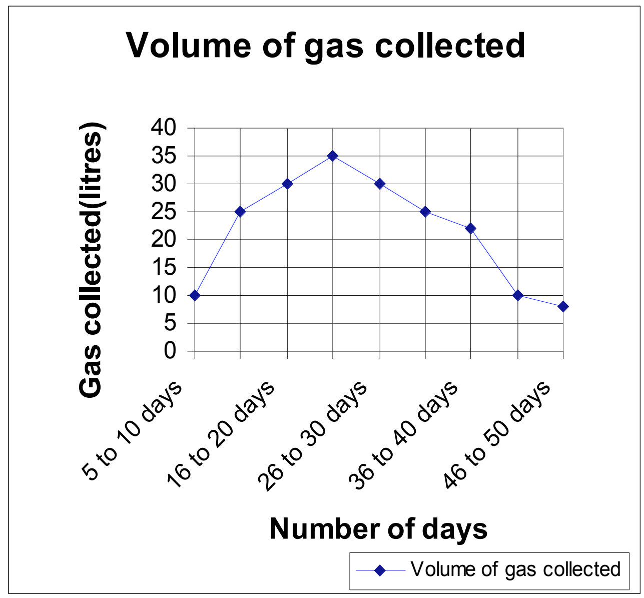


Fig. (4). Volume of gas collected for 5% seeding.

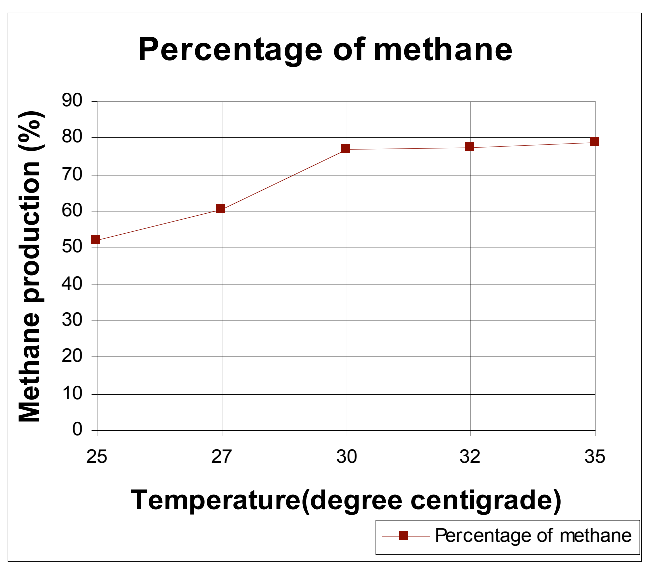


Fig. (5). Effect of temperature on methane formation.

Table 8. Specifications of the Engine

General Details	Four stroke, Single cylinder, Water cooled
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5 : 1
Rated output	5.2 kw @ 1500 rpm
Injection pressure	200 bar
Fuel injection timing	23^0 BTDC

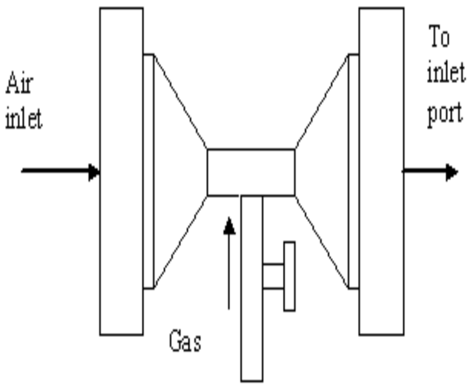


Fig. (6). Venturi attachment.

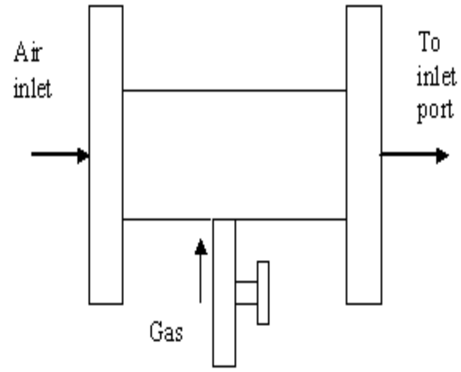


Fig. (7). T joint attachment.

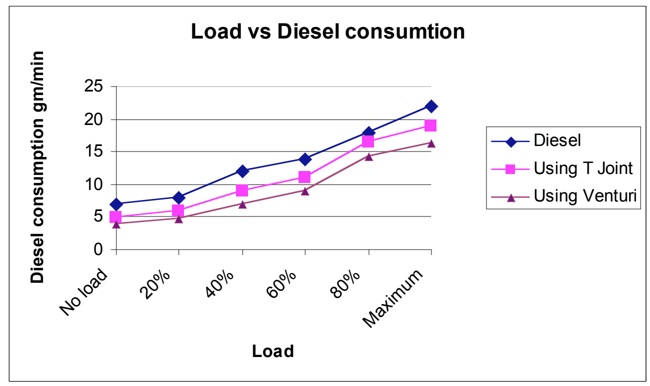
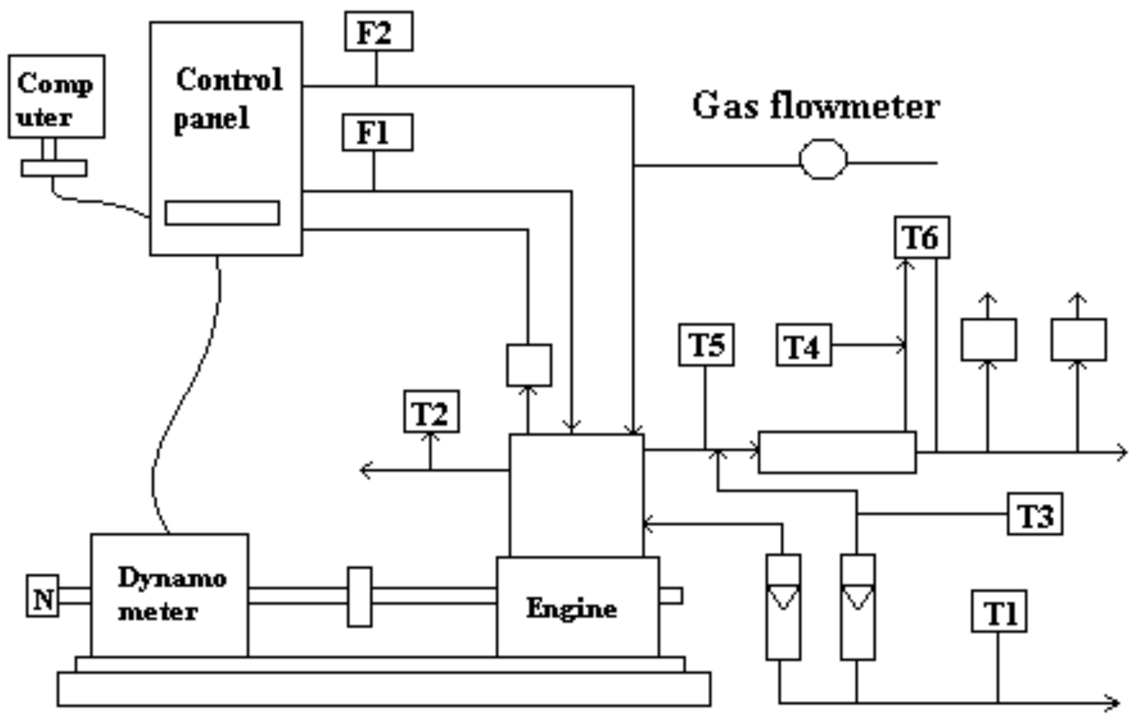


Fig. (8). Diesel saving for different attachments.



T1&T3 - Inlet water temp °C

T2 - Outlet engine water temp °C

T4 – Outlet calorimeter water temp °C

T5 – Exhaust gas temp °C before calorimeter

T6 – Exhaust gas temp °C after calorimeter

N – RPM decoder

F1 – Fuel flow differential weight unit

F2 – Air flow differential velocity unit

Fig. (9). Experimental setup to analyze diesel consumption.

It was found from Fig. (**8**) that venturi attachment saves more diesel than T joint attachment as the turbulence of the gas air mixture is increased.

CONCLUSIONS

Generally, in textile mills waste like, fly, raising fly, flat strip, dirty cotton, etc are lifted for open-end yarning and fetches approximate value of INR 5 to 7/- per kg (USD 1 = INR 40). Depending on the quality of waste, some grades are not utilized for any purpose. Also, open-end yarning waste that amounts to 10.5% will have no use and degraded by the way of burning. The problem of cotton waste has now assumed serious dimensions, since it pollutes the atmosphere. Spinning mills may be in the advantageous position to utilize the biogas, which can be produced in their premises to avoid the problem of pollution. From the experimental results it was found that:

- Cotton waste can efficiently be used as potential resource for biogas generation if proper conditions are maintained.
- Biogas production from cotton waste can be increased with cow dung, pig dung and goat dung as seeding material.
- 5 to 7.5% of cow or pig dung with cotton waste by weight generates around 77% of methane against 60% in other techniques and thereby increases the volumetric calorific value.
- The production rate is high from 15^{th} day to 30^{th} day after starting fermentation
- The optimum temperature for gas production is found to be 30 to 32^0C.
- Around 60% of diesel can be saved by using biogas as dual fuel, but more work to be made on the control of emission and performance of combustion.
- From the experimental study, it is clear that the use of venturi at the inlet port of the engine is effective method to supply the bio gas.
- The bottled biogas can be used as a dual fuel in CI engine fitted automobiles to reduce fossil fuel consumption

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