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To Study the performance of developed Biogas Plant from jatropha oil cake for domestic application

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ABSTRACT: *The field experiments for biogas production from Jatropha Oil Cake (JOC) and details of various analytical methods used in determination of physico-chemical characteristics of substrates before and after anaerobic digestion. The experiments were conducted at GopalPura (Bhindar) for Green Oil Energy Sciences (GOES) (Pvt) Ltd, New Delhi. This Biogas plant was developed during the year 2010, with the help of following experimental details.*

Plant capacity and dimensions of flexible balloon digester , total volume of the digester, biogas storage balloon , hydrostatic pressure, earth pressure, design parameters such as hoop stress, longitudinal stress, circumferential strain, longitudinal strain, change in diameter, change in length, original volume, thickness of balloon and chemical composition of Jatropha oil cake moisture content, total solids, volatile solids, non-volatile solids, nitrogen, phosphorus, potassium, carbon, C:N ratio, crude protein and oil content, characteristics of JOC before and after anaerobic digestion. Nutrient content of Jatropha oil cake before and after anaerobic digestion. The biogas generated from FBSD was used for domestic purposes by using biogas double burner stove. Gas engine was tested to observe its performance using biogas for power generation.

Key words: *Biogas, Domestic, Energy ,power generation*

Worldwide energy consumption and demand are growing up since past 50 years . Most of the resources used like petroleum, natural gas, coal are not sustainable sources of energy. Numbers of countries in the world including India are currently passing through the critical phase of population explosion and the growing population demands more energy inputs. In March, 2011 India had 17% of world's population and ranked first for high population density of 371 people per Km2. Indian per capita energy consumption is as low as 700 kWh while the world's average is 2,500 kWh and for many of the developed countries the figure is 15,000 kWh. In India there is deficiency of energy in required form to meet national developmental needs.

Biofuels are capable of minimizing the oil import and pollution; therefore these can be the best alternatives in securing the energy needs of India. Though conventionally Indian population is dependent on biofuels such as cow-dung cake, wood etc but there are problem associated such as ease of use, availability throughout the year, health problems, operating issues, energy gain, by-products or waste generated and pollution. For example in rural India, due to use of fuel wood adverse health impacts on women are observed . Inefficient cooking is seen due to use of traditional cook stoves, with efficiency range of 10-14%. Therefore there is a requirement of energy in India to satisfy the energy demand and which is environment friendly. To fulfill energy demand of Indian population, the strategy must focus on basic seven goals which are cost minimization, efficiency maximization, employment generation, system reliability, minimization of petroleum product, maximization use of local resource, and minimization of emissions.

Biogas is the gas produced after anaerobic digestion of organic matter by microorganisms. The biogas is in use since long time in India but the technology improvement is necessary in order to improve energy outputs. Indian energy scenario and drivers for bioenergy regularization in India are

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discussed in the review. General benefits of biogas technology and applications are mentioned.

Biogas is a gaseous mixture generated during anearobic digestion processes using waste water, solid waste (e.g. at landfills), organic waste, e.g. animal manure, and other sources of biomass (Welink et al., 2007). Anaerobic digestion is the biological degradation of biomass in oxygen-free conditions. In the absence of oxygen, anaerobic bacteria will ferment biodegradable matter into methane (40-70%), carbon dioxide (30-60%), hydrogen (0-1%) and hydrogen sulfide (0-3%), a mixture called biogas. Biogas is formed solely through the activity of bacteria. Although the process itself generates heat, additional heat is required to maintain the ideal process temperature of at least 35°C. In comparison, the methane component of natural gas could amount to over 80%. In nature, biogas is generated at the bottom of stagnated ponds, lakes, swamps or in the digestive system of animals (Jepma *et al.*, 2006).

Biogas technology is a vital component of the alternative rural energy program in Africa. Biogas generation is a renewable energy technology that utilizes organic waste sources to produce a flammable methane gas suitable for cooking and lighting purposes (Lansing, *et al.,* 2008). This technology has the potential to provide an alternative to the current unsustainable biomass sources and provide environmental, social, and economic benefits. Biogas technology has not yet been successfully adopted as either an energy or economic strategies, potentially serving as a means to overcome energy poverty, poses a constant barrier to economic development 6Biogas is a high-grade fuel; it can be used in gas mantle for lighting purposes or internal combustion engines like dual fuel engines (adopted diesel engine) for electricity generation. Although biogas lighting, using mantle lamps similar to kerosene pressure lamps, cannot compete with the comfort of electric lighting, it may offer the best option for lighting in areas that are not connected to the grid. 2.3 Improved food production Factors that control crop production include uptake of nutrients, water and oxygen, light interception, and temperature. The environmental constraints that directly impact these factors include availability of nutrients, organic matter content of the soil, water availability and climate. The widespread introduction of biogas digesters is likely to have an impact on all of these environmental constraints. Biogas digesters can improve the nutrition of households through the application of the effluent (slurry) as an organic fertilizer to improve agricultural yield (LEISA, 2005; Kangmin and Ho, 2006).

The evaluation of 2-m^3 rubber-balloon biogas plant under hilly conditions and compared with a fixed-dome type Deenbandhu biogas plant of the same capacity. The daily average biogas production in the rubber-balloon plant was 0.92 m^3/d, compared to 1.23 m^3/d in the Deenbandhu plant. The difference in biogas production was 33.7%. A reduction of about 77% was found in the rate of biogas production from the rubber-balloon plant during winter months as compared to production during the summer months. The corresponding reduction in production of gas from the Deenbandhu biogas plant was only 16%. The methane contents of the biogas of both the plants were almost identical, but the moisture in the gas was 43% higher in the rubber-balloon than in the Deenbandhu plant. They concluded that the changes in ambient temperature affected the rubber-balloon plant more than they affected the conventional plant (Kanwar *et al.,* 1994).

IARI (1993) constructed a set of five digesters made of plastic interconnected in series through a metallic gas pipe system having one gas outlet using subabul and cattle dung as feed material. After the initial digestion for 60 days each digester in turn was replaced with fresh feed at an interval of 12 days. Subsequently the constant cycle of 12 days was maintained thus allowing every feed lot in each of the digester to digest over a period of 60 days. The cumulative gas evolved was collected over water in floating type gas holder and was measured daily. Average daily gas production noted was about 28 liter/kg dm in the first week to 275 liter/kg dm in the 17th week.

Meher *et al.,* (1995) evaluated the biodegradation of tobacco waste, under methanogenic conditions, which invariably reduced environmental pollution while producing biogas as a useful energy source. The methanogenic bacterial consortium was developed for the anaerobic degradation of tobacco waste without any chemical pretreatment in a single stage digester at 15 days HRT. This setup had been successfully scaled-up to install a 10 m^3 biogas plant. The gas yields (1 kg TS fed/ day) varied from 169 to 282 L depending on the ambient temperatures. The methane content in the biogas produced was 60%. The pH and VFA content of the digested slurry were 6.8 ± 0.1 and 599 mg $litre^{-1}$, respectively. Nicotine, COD and BOD reductions were 75, 60 and 80%, respectively.

Keeping in view the importance of biogas as renewable energy sources and limitations of Jatropha Oil Cake in present energy quest, this study entitled "Design and Development of Biogas Plant from Jatropha Oil Cake".

Initially the biogas plant was filled with cattle dung mixed with water (1:1) and proper volume of inoculum. It was operated for 40 days. It was done to facilitate proper growth of bacterial families. After stabilization of methanogenic process, feeding with JOC with dilution ratio 1:3 (JOC : Water) was started. The 10 per cent of daily feed dung was gradually replaced by JOC. After complete replacement of feed by JOC the plant was started feeding JOC alone along with the required water. Then recording of observations were started and continued for 8 weeks period of operation.

After commissioning of the plant as described above, observations of biogas generation was taken daily, while other parameters like solid content, volatile solid content, pH were taken after each 10 days period. Based on these observations, process parameters and performance were evaluated. The chemical composition of Jatropha Oil Cake used for this experiment was measured initially and the per cent of various components in it are presented in Table 2. (Kumar & Kurchania 2009, Dhanya *et al* 2009)

The physical characteristics of Jatropha Oil Cake before and after digestion such as total solids, volatile solids and pH were taken and subsequently it was observed at an interval of 10 days during the 8 week period of operation. The observations are given in the Table 3. Bhattacharya (1993) It was observed that the average total solid of inlet charge was 10.11% that reduced to 7.47% for the digested slurry on an average. Average volatile solid of inlet charge was 88.93% and for the digested slurry average volatile solid was 65.83%. The average per cent loss of volatile solids after digestion was observed as 22.89%. The average pH of the slurry in the inlet was 7.34, whereas the average pH of the outlet slurry was 7.81.

Biogas spent slurry was analyzed for nutrients like nitrogen, phosphorus and potassium at every 20 days interval. Table 4 shows the nutrient content of JOC slurry before and after anaerobic digestion. The average nitrogen content in the fresh slurry was 3.05% and in the digested slurry was 3.83%. The average maximum increase of 25.78 per cent nitrogen content in the digested slurry was observed. On an average 1.95% phosphorous was found in fresh slurry and 2.16% in the digested slurry of the plant. Also on an average 10.96% increase in the phosphorous content was observed. Potassium content in the fresh slurry was 1.28% while it was 1.54% in the digested slurry. On an average of 20.31% increase in potassium content was observed.

UTILISATION OF BIOGAS

Biogas for domestic use

The biogas generated from FBSD was used for domestic purposes by using biogas double burner stove. In this stove, size of one burner was 450 and other was 225 liter per hour capacity. The biogas was supplied to biogas burner by connecting the pipeline from storage balloon to burner. Cooking and other milk processing operations such as ghee, mava making etc were performed by using the biogas stove. Previously used LPG for performing these thermal operations was replaced by the biogas produced from FBSD.

Gas engine set up was made for testing purpose at GopalPura (Bhindar). The power generated from biogas produced from FBSD, was evaluated for its performance. Performance of gas engine was done at different generator loads. From this brake thermal efficiency and specific fuel consumption was calculated.

Table 1
Study of Design of flexible balloon stirring digester

Hydrostatic pressure	21991.2 Pa.
Earth pressure	1428 Pa
Net force	20563.2 Pa.
Design parameters	
Hoop stress	37.96 MPa
Longitudinal stress	18.98 MPa
Circumferential strain	10.84×10^{-3}
Longitudinal strain	3.65×10^{-3}
Change in diameter	21.7 mm.
Change in length	10.9 mm
Original volume	9.42 $m^{3.}$
Thickness of balloon	0.8 mm

Table 2
Study of chemical composition of Jatropha Oil Cake taken for the experiment

S.No	*Component*	*Jatropha Oil Cake %*
1.	Moisture content	5.82 (w.b)
2.	Total solids	94.18 (w.b)
3.	Volatile solids	88.43 (w.b)
4.	Non-volatile solids	6.2
5.	Nitrogen	3.67
6.	Phosphorus	2.03
7.	Potassium	1.41
8.	Carbon	49.87
9.	C:N ratio	13.59
10.	Crude Protein	22.93
11.	Oil content	6.6

Table 3
Study of characteristics of JOC before and after anaerobic digestion

Days of observation	*Total solids*		*Volatile solids*		*% loss of volatile solids after digestion*	*pH*	
	BD	*AD*	*BD*	*AD*		*BD*	*AD*
1	10.12	7.89	88.32	65.14	23.18	7.3	7.8
11	10.08	7.43	90.58	65.38	25.20	7.2	7.7
21	10.41	7.78	88.34	68.72	19.62	7.5	7.8
31	10.03	7.65	87.48	64.88	22.55	7.3	7.9
41	9.86	7.38	91.25	67.18	22.60	7.4	7.8
51	9.85	7.00	90.14	65.65	24.49	7.3	7.9
61	10.40	7.14	86.42	63.86	22.56	7.4	7.8
Avg	10.11	7.47	88.93	65.83	22.89	7.34	7.81

Table 4
Study of nutrient content of Jatropha Oil Cake before and after anaerobic digestion

Days of observation	*Nitrogen %*			*Phosphorus %*			*Potassium %*		
	Fresh Slurry	*Digested Slurry*	*% increase after digestion*	*Fresh Slurry*	*Digested Slurry*	*% increase after digestion*	*Fresh Slurry*	*Digested Slurry*	*% increase after digestion*
1	2.47	3.12	26.31	2.06	2.27	10.19	1.25	1.5	20.00
21	2.53	3.28	29.64	1.72	1.91	11.04	1.12	1.38	23.21
41	3.45	4.25	23.19	1.87	2.10	12.30	1.33	1.60	20.00
61	3.75	4.65	24.00	2.13	2.35	10.32	1.4	1.69	20.71
Average	3.05	3.83	25.78	1.95	2.16	10.96	1.28	1.54	20.31

Table 5
Performance Evaluation of Gas Engine run on Biogas

Generator Load (kW)	*Engine Speed (rpm)*	*Biogas Consumption*			*Brake Specific Biogas Consumption*			*Energy Input (kW)*	*Brake Thermal Efficiency (%)*
		l/min	*kg/h*	*m^3/h*	*kg/kWh*	*m^3/ bhp-h*	*m^3/ kWh*		
Ideal load	1475	45.82	1.924	2.749	**-**	-	-	14.07	0
1	1382	46.81	1.966	2.808	**1.966**	2.111	2.80	14.37	6.95
2	1346	43.38	1.822	2.602	**0.911**	0.978	1.30	13.32	15.01
3	1445	58.57	2.460	3.514	**0.820**	0.880	1.71	17.99	16.67
4	1260	53.24	2.236	3.194	**0.559**	0.600	0.79	16.35	24.46
5	1358	73.69	3.095	4.421	**0.619**	0.664	0.88	22.63	22.08

Table 5 shows Maximum Brake Thermal Efficiency of engine on biogas was 24.46 % at 4 kW generator load. Maximum and minimum brake specific fuel consumption of the engine on biogas was 2.80 m^3/ kWh at 1 kW and 0.79 m^3/ kWh at 4 kW respectively.

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