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Design and Development of Jatropha Oil Cake Based Flexible Balloon Stirring Digester Biogas Plant

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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.

Key words*: Digester, Capacity, Stirring unit, Slurry.*

As the demand for the fossil fuel increases, their prices rise, interest has rightly begun to be given to the development of renewable energy sources. Renewable sources of energy offer the most potential energy conservation and development option for future. The use of renewable energy sources can meet considerable energy demand of several villages in a country. The most commonly available renewable sources of energy are Biogas, Solar, Wind, Biomass, etc. Of the various renewable energy sources mentioned above, Biogas has been developed and utilised to the maximum extent possible in India. During 2007-08, India imported 68 % of the total oil consumption of 156 million tonnes (MT) worth '2415.39 billion (Ministry of Finance, India). The current disposal practices for the agricultural residues have caused wide spread environmental concern as they represent hindrance in sustainable development in rural areas as well as to the national economy (Kivasisi and Mtila, 1998, Imbeah, 1998).

Anaerobic digestion is widely used as a renewable energy source because the process produces a methane and carbon dioxide rich biogas suitable for energy production helping to replace fossil fuels. Also, the nutrient-rich digestate can be used as fertiliser. Anaerobic digestion is a versatile, effective and established method that is being used world-wide for the digestion of different organic wastes and the production of energy in the form of biogas (Ahring *et al*., 1992; Verstraete *et al*., 2005).

Methane is a flammable, odourless and tasteless gas. It is not considered as a toxic gas; it may, however, be an asphyxiant; at high concentration it displaces the oxygen required to sustain life. Methane is nearly always handled as a gas, since its critical temperature (– 82.5 °C) and pressure (47.3 kg/cm^2) are high, methane cannot easily be liquefied. Thus, unlike some other gases used as energy sources, it is difficult to compress into a smaller volume. Methane and power produced in anaerobic digestion facilities can be utilized to replace energy derived from fossil fuels, and hence reduce emissions of greenhouse gases.

Organic waste materials of agricultural, industrial and municipal origin can be anaerobically converted into biogas by the action of rumen microorganisms (Gijzen *et al*., 1987). This technology has the potential

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to short-circuit the 'energy transition' from biomass to 'modern' fuels (Kaparaju and Rintala, 2003).

The use of biomass to provide energy has been fundamental to the development of civilization. Biomass contributes a significant share of global primary energy consumption and its importance is likely to increase in future world energy scenarios. The search for ecologically sustainable alternative energy for diesel ended in biodiesel production from vegetable oil, particularly non-edible oil from Jatropha curcas. *Jatropha curcas* in the Euphorbiaceae family grows well under adverse climatic conditions because of its low moisture demands, fertility requirements, and tolerance to high temperatures and contains approximately 170 known species (Augustus *et al.*, 2002). *Jatropha curcas*, a multipurpose, drought resistant, perennial plant is gaining a lot of importance for the production of biodiesel. It is commonly known as pysic nut or purging nut. Nearly 40% of the land area in India is wasteland. Importance is given on the plantation of *Jatropha* species on wastelands, for the protection of the environment and fulfilling future energy requirements.

Seed yield varies from 2-3 kg/plant to 4-6 kg/plant. The oil content in seed varies from 31 to 37%. On an average 3.28 kg of seed gives one liter of oil. Oil seeds are used for extraction of oils such as Jatropha oil to produce Biodiesel. After extracting oil from the seeds the remaining matter that is left behind as byproduct is oil cake. Jatropha oil cake contains toxic alkaloid called jatrophine therefore it is non-edible. One tonne of Jatropha Curcas seeds yields 300 kg oil products and 700 kg oil cake. One tonne per day biodiesel plant produces 2.5 to 3 tonnes of seed cake (Lele, 2006). These oil cakes such as Jatropha oil, Pongamia oil, castor oil cakes etc. are rich in nutrients and can be used for a wide variety of applications. Jatropha Oil Cake can be used as good organic fertilizer. One of the major problems arising is disposal of cake after expelling oil from seed. The cake can neither be used for animal feeding nor directly can be used in agricultural farming due to its toxic nature. The generation of biogas from these cakes would be a best solution for its efficient utilization. Biogas from cake provides energy for heating, cooking, lighting and engine operation and digested cake slurry can be directly put for agricultural farming. Total biogas generation potential from Jatropha curcas cakes in India has been estimated as 2, 550 million cubic metres from 10.2 lakh metric tonnes of Jatropha curcas oil cakes (Ram Chandra *et al.*, 2006). Jatropha oil cake is a very good substrate for biogas production because of its high protein and mineral content.

The wood and fruit of *Jatropha* can be used for numerous purposes including fuel. The seeds of *Jatropha* contain viscous oil, which can be used for manufacture of candles and soap, in cosmetics industry, as a diesel/paraffin substitute or extender. This latter use has important implications for meeting the demand for rural energy services and also exploring practical substitutes for fossil fuels to counter greenhouse gas accumulation in the atmosphere. These characteristics along with its versatility make it of vital importance to developing countries (Kashyap and Foidl, 2003). In addition to being a source of oil, *Jatropha* also provides a meal that serves as a highly nutritious and economic protein supplement in animal feed, if the toxins are removed. For mitigating climate change by reducing emission of green house gases, meeting rural energy needs, protecting the environment and generating gainful employment, Jatropha curcas has multiple roles to play (Lele, 2006). Biogas production units provide a decentralized fuel supply and waste management system, both of which are very attractive particularly in rural areas of developing countries (Pound *et al.*, 1981, Staubmann 1996, Yati *et al.*, 2008).

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 Jatropha Oil Cake based Flexible Balloon Stirring Digester Biogas Plant".

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

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)

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

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.

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

	Total solids		*Volatile solids*			*pH*	
Daysof observation	*BD*	*AD*	*BD*	*AD*	*% loss of volatile solids after digestion*	*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

	Nitrogen %			*Phosphorus %*			*Potassium %*		
Days of observation	*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

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