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Full Length Research Paper

Bio-methanisation of *Jatropha curcas* defatted waste

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The study deals with the use of *Jatropha curcas* defatted waste as an alternative feed in biogas plant for its bio-methanisation. As it remains as defatted cake after the extraction of non-edible oil from *Jatropha* seeds, it cannot be used directly for any purpose due to presence of toxic substance called 'curcin'. This toxin renders it unsafe for the animal feed and other purposes. It contains 5.73% nitrogen, 1.5% phosphorus and about 1% potassium. On the basis of its chemical composition, its application as substrate to the biogas plant can be a sustainable alternative as compared to the other applications of *Jatropha* press cake. The study was conducted on a floating drum type biogas plant. It was observed that the biogas plant, initially charged with pure cattle dung, when gradually replaced with *Jatropha* oil cake (0 - 100%), it increased the biogas production up to approximately 25% in reasonable time duration. A significant increase in the percentage of nitrogen, phosphorus and potassium during the bio-fermentation process invokes the use of the effluent slurry as organic manure. Simultaneous reduction in the amount of the oil (5.67 to 3.95%) sustains the possibility of degradation of oil during methanisation. The plant has showed higher biogas yields at low temperatures also. Therefore, *Jatropha* defatted waste can successfully be used as a adduct as well as substrate in already running cattle dung based biogas plant to get high yield of biogas in comparison to cattle dung feed.

Key words: *Jatropha* oil cake, biogas production, gas yield, Pragati biogas plant.

INTRODUCTION

Various forms of biomass such as vegetation, animal dung and plant products are providing safe and convenient sources of energy as in the form of biogas and liquid fuel. Biomass such as cattle dung, agro-residues, plant residues, organic wastes from industrial processing in spite of being biodegradable, create much nuisance in the environment. These easily available alternative resources can be harnessed by anaerobic fermentation of this waste matter producing biogas as efficient gaseous fuel. Although there are technological hurdles in this area of research yet they have proved to be much more efficient and environment benign than non-conventional sources of energy. During past 20 years several modifycations in biogas plants have been done to overcome the technological and operational hurdles like modifications are done in Deenbandhu and KVIC biogas plants to run them on high solid concentration of cattle dung for attaining higher biogas production (Maheshwari et al., 2006).

India produces a host of non-edible oils, which are essentially under-utilized and can be used for oil extraction and Bio-diesel production. These non-edible oils can be obtained from Rice-bran, Sal, Neem, Mahua, Karanja, Castor, linseed, *Jatropha*, honge, rubber-seed etc. Most of these trees and crops grow well on wasteland and can tolerate long periods of drought and dry conditions. Among them, *Jatropha* has several more desirable properties such as hardiness, wide environmental tolerance, can grow on any type of soil, adapt well to waste

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Abbreviations: KVIC, Khadi Village Industries Commission; **TS,** Total Solids; **VS,** Volatile Solids; **N,** Nitrogen, **P,** Phosphorus; **K,** Potassium; **MW,** Mega Watt; **l/kg dm,** litre/ kg of dry matter; **CD,** Cattle dungm; **JC,** *Jatropha* cake; **T,** Treatment.

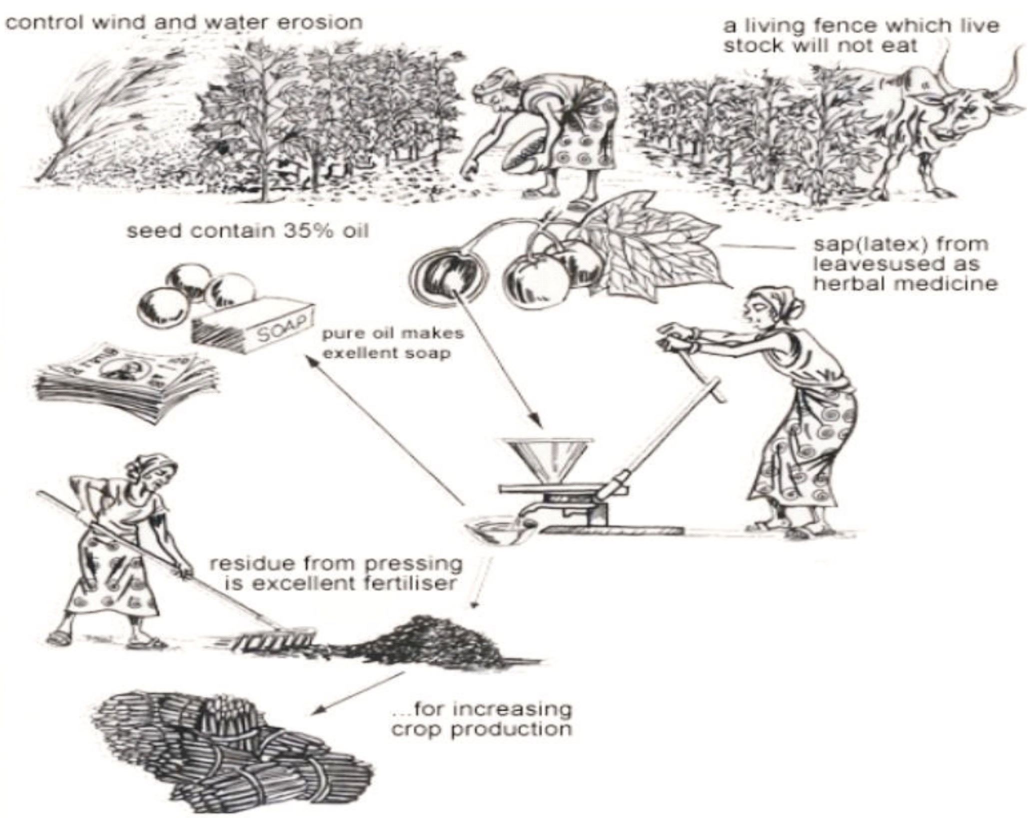

Figure 1. Processing of *Jatropha* seed.

landeasy propagation and high oil content and require minimal care. It has less gestation period, rapid growth and is not browsed by animals. This plant provides ample opportunities for wealth generation among marginal sections of the society, women empowerment and rural employment (Agarwal, 2007).

Jatropha contains about 30% oil leaving behind press-cake (75% including near about 5% losses of oil in extraction process in the mechanical expeller) with residual oil. The oil is being used for preparing bio-diesel (Achten et al., 2008) and in soap preparation (Figure 1). The press cake is rich in organic matter (Abreu, 2007). It can be used as manure, as feedstock for biogas production, animal feed etc. (Agarwal, 2007). Conventionally, *Jatropha* oil cake is being used for soil enrichment (Reyadh, 1997). *Jatropha* oil cake as an organic fertilizer is superior to cow-dung manure and is in great demand by the agriculturists (Envis, 2004). But defatted *Jatropha curcas* waste (press cake) contains certain phytotoxins (TNAU, 2005) like curcin which cannot be directly used for animal feed and plant growth. However, this residue can serve as good substrate in biogas plant for biogas production owing to its rich mineral and protein content (FAQ, 2006; Staubmann, 1981).

Considering 25% oil yield, an oil extraction plant of capacity 10,000 ton per year will produce 7500 ton of de-oiled cake every year. This large amount of defatted cake remaining after oil has been expelled can be used for biogas plant feed to generate biogas. This biogas can be used to run dual fuel generators to produce electricity. A plant of 2500 ton bio-diesel capacity will produce 1.5 MW power from biogas at very less investment compared to conventional power projects (Mint, 2006). Total biogas generation potential from *Jatropha curcas* cakes in India has been estimated as 2, 550 million m^3 from 10.2 lakh metric ton of *J. curcas* oil seed cakes (Ram Chandra et al., 2006).

MATERIALS AND METHODS

First of all, the feasibility of the *Jatropha* as feed for biogas plant was tested for its consistency, density, total and volatile solid content, carbon and nitrogen content. The results obtained have been shown in Table 1. Since the hulls (press cake) have low density, it is not of economic interest to transport them over long distances for processing. Its use as biogas plant feed can be a lower cost, environmentally sustainable, long-term solution for handling *Jatropha* hulls is therefore of critical importance (Sharma et al. , 2009).

The laboratory study was done in batch type digester (capacity-2 L) containing different proportion of cattle dung and *Jatropha* cake. The various proportions of cattle dung and *Jatropha* and the gas production can be depicted accordingly (Table 2). The results tabulated are the calculated average of the three replications. The dilution factor for press cake was optimally taken as 1:4 (Ram Chandra et al., 2006).

Table 1. Biochemical analysis of cattle dung and *Jatropha* oil cake.

Substrate	TS %	VS %	C%	N %	P %	K %	C/N ratio	Oil content %
CD	22.84	86.77	50.33	0.72	0.07	0.08	70:1	nil
JC	90.89	78.56	45.56	5.73	1.75	0.94	8:1	5.67

TS; Total solids, VS; Volatile solids, N; Nitrogen, P; Phosphorus, K; Potassium, CD; Cattle dung, JC; *Jatropha* cake.

Table 2. Treatments of *Jatropha* cake mixed with cattle dung.

Treatments	JC (gm)	CD (gm)	Water (ml)	Ratio (JC:CD)	Biogas (l/kgdm)
T_1	631.60	-	1500	100:0	50.00
T_2	315.80	1500.00	2000	50:50	160.00
T_3	157.90	2250.00	2000	25:75	205.00
T_4	472.52	375.00	1500	75:25	84.00
T_5	-	1000.0	1000.0	0:100	175.00

CD; Cattle dung, JC; *Jatropha* cake.

Figure 2. Prefabricated plant for laboratory study.

Laboratory study was then carried out in a continuous type fiber glass biogas plant (capacity = 70 L) charged initially with 80 kg of cattle dung slurry (1:1) to study slow replacement of cattle dung by *Jatropha* oil cake. The experiment was performed in triplicate. The *Jatropha* cake was presoaked in water (for one day) to prepare homogeneous slurry with water. Daily charging was done at the rate of 2 kg per day. The study of the plant was done for one year for shifting the technology to the field. The biogas was being tested for its flammable character (Figure 2).

Investigation in the field was carried out on two KVIC biogas plants of capacity 1m^3, Experimental plant (EP) (figure-3) and Control Plant (CP) at Department of Renewable Energy Sources, College of Technology and Engineering, Udaipur. A control biogas plant was also operated fed only on cattle dung for comparative evaluation of the technology. The KVIC biogas plants were initially charged with cattle dung water mixture {1:1 (2500 kg)} having 10 – 15% total solids (TS). The Experimental (*Jatropha* based) biogas plant was first fed with cattle dung for the development of sufficient microbial culture for biogas production. Both the plants were regularly fed with cattle dung slurry at 50 kg per day for stabilization for one month.

After its stabilization, the cattle dung was slowly replaced with pre-soaked *Jatropha* cake to an extent of 100%. Feeding was started up with small quantity of press cake so that bacteria can adapt themselves to the new composition of substrate (*Jatropha* system, 2006). The Experimental bio gas plant was fed with a slurry mixture of fixed proportion of presoaked *Jatropha* oil cake and cattle dung so as to substitute conventional feed by *Jatropha* oil cake. After an interval of every 10 days, 2.5 kg of cattle dung was replaced with 1 kg *Jatropha* cake thus replacing 25 kg cattle dung with 10 kg *Jatropha* cake to observe the efficiency of defatted *Jatropha curcas* cake in enhancing biogas production under anaerobic condition. The plant was operated solely on *Jatropha* cake after development of sufficient microbial consortium in the digester. Daily gas production was measured using wet type gas flow meter in liters (least count = 0.05 L). The results have been reported as biogas yield in liters per kg of dry matter (l/kg dm). The biochemical analysis of the *Jatropha* oil cake, cattle dung and the influent and effluent slurry of the biogas plant were done by standard methods of analysis of the biomass. The volatile solids were estimated by muffle furnace method; nitrogen content by kjeldhal method; phosphorus by spectrophotometric method; and potassium by flame photometric method.

RESULTS AND DISCUSSIONS

Preliminary studies showed that *Jatropha* oil cake has essential components for biogas generation such as volatile solids, carbon, nitrogen, potassium and phosphorus (Table 1). It has high quantity of proteins and lipids that can be used by microbes during anaerobic methanisation (Makkar, 1997).

Batch study

In laboratory study as depicted by Table 1, the maximum

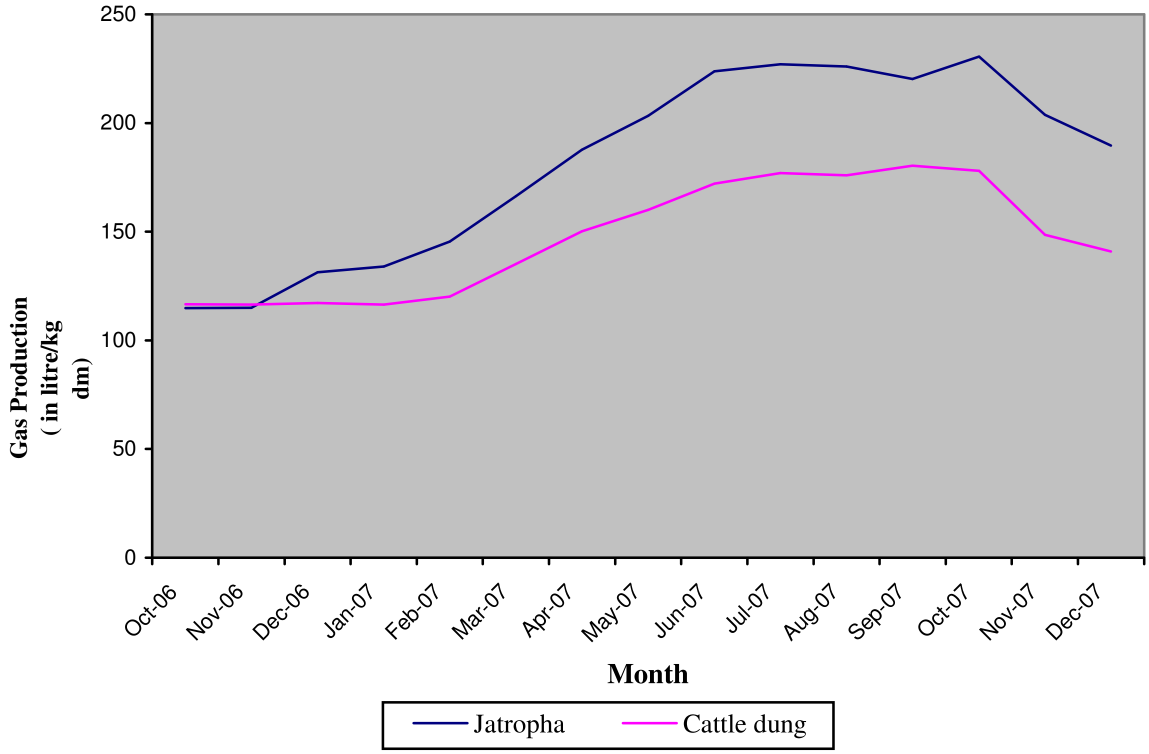

Figure 3. Annual Variation in *Jatropha* based biogas plant with respect to control.

biogas production was observed in Treatment T_3 with 205.0 l/Kg dm which is 18% greater than treatment T_5 (conventional feed of cattle dung- control). T_3 treatment consists of 25% of *Jatropha* oil cake and 75% of the conventional feed cattle dung. However, the treatment T_2 with *Jatropha* cake: Cattle dung ratio of 1:1 also showed satisfactory results as compared to cattle dung. However, it was also concluded that *Jatropha* cake alone cannot develop sufficient microbial population for optimum biogas yield. So, the elaboration of the technology to the field would require an initial inoculum of microbes so that the initially charged feed can act as seeding material for new feed.

Field study

The laboratory results were tested in the field using a continuous type fibre glass plant of capacity. To run a biogas plant fed solely on *Jatropha* cake, initially it was charged with cattle dung and then slowly replaced by *Jatropha*. The technique was found suitable in the continuous system and an average of 65 L of flammable gas was produced per day.

In field study, the observations were taken from date of first charging of the plant followed by its stabilization and complete replacement of cattle dung by *Jatropha* oil cake. The plant was then operated on 100% *Jatropha cake* cake feed for a year and monitored simultaneously. The daily charging was done with 10 kg *Jatropha* cake mixed with 40 kg of water (dilution factor 1:4). The results were analyzed statis-tically using paired t- test and the resultant t-value (= 2.048) was found significant. Initially, both the plants showed similar gas production of approximately 115.0 l/kg dm as similar feed was provided. Afterwards, during replacement, initially the gas yield increased sharply with a steep slope followed by constant increase with respect to cattle dung (Figure 3) like as in the fifth month itself, a drastic increase of 21% was observed over control (biogas production in February 2007 was 145.38 l/kg dm).

Results reveal that monthly mean biogas production increased from 116.5 l/kg dm in November 2006 to highest of 230.6 l/kg dm in the month of October 2007. Average biogas production showed 23.26% increase (over control) in *Jatropha* based biogas plant with an average gas yield of 181.25 l/kg dm as compared to cattle dung based biogas plant with an average gas yield of 147.05 l/kg dm (Figure 4).

The biogas production showed direct relationship with the temperature as it directly affects the rate of bio-methanisation (Table 3). Higher temperature favors high rate methanisation thereby increasing gas production. Thus, high yield of biogas is obtained in summer season (Temperature = 35 - 40℃). The observed summer maxi-mum value of biogas is 226.95 l/kg dm in *Jatropha* based

Table 3. Annual variation of gas yield in *Jatropha* based biogas plant with respect to control plant with temperature.

Month	Gas production (L/kg dm)		Temperature (°C)	
	Experimental plant (*Jatropha*)	Control (cattle dung)	Max.	Min.
Oct 06	114.86	116.86	32.00	15.26
Nov	115.01	116.50	28.34	9.65
Dec	131.31	117.24	25.80	7.60
Jan 07	133.98	116.50	25.88	5.31
Feb	145.38	120.15	31.84	9.90
March	166.32	135.22	32.25	11.83
April	187.65	150.12	37.85	19.34
May	203.33	160.10	38.28	24.60
June	223.80	172.15	35.77	26.50
Jul	226.95	176.98	30.94	24.52
Aug	225.90	175.98	29.87	23.25
Sept	220.34	180.40	31.85	21.57
Oct	230.60	178.09	32.78	12.72
Nov	203.64	148.56	30.72	9.30
Dec	189.65	140.95	28.65	10.04
Average	181.25	147.05		
% increase	23.26			
T value @ 5%	2.048			

Table 4. Chemical analysis of inlet and outlet slurry.

Bio gas plant	Inlet slurry					Outlet slurry				
	TS%	N%	P%	K%	Oil%	TS%	N%	P%	K%	Oil
Jatropha	10.76	3.51	2.06	0.66	5.67	8.87	5.56	2.90	1.24	3.95
Control	9.64	0.54	0.49	0.51	-	7.22	1.42	1.04	1.02	-

Figure 4. *Jatropha* based biogas plant (floating drum type).

biogas plant which crawled to 180 l/kg dm in control fed on cattle dung slurry. Similarly, biogas production decreases in winter season when the mean temperature is lower (8 - 12°C). During winter period of 2007, the gas production decreases from 230.6 l/kg dm in October to 189.65 l/kg dm in December 2007. It has been showed that biogas from *Jatropha* has higher calorific value due to higher methane content (Abreu, 2007).

The bio-digested slurry from *Jatropha* oil cake is another important product from the biogas plant. This slurry can serve as good manure owing to its high nutrient composition (Table 4). The slurry from *Jatropha* biogas plant contains 5.56% nitrogen, 2.90% phosphorus and 1.24% potassium.

It is much higher than fresh *Jatropha* cake, fresh cattle dung and its bio-digested slurry. The oil content in the press cake is also reduced from 5.67% to 3.95%. Thus, it may be concluded that residual oil in the cake also degrades during the anaerobic fermentation of the *Jatropha* oil cake. Attempts are being made at the centre to efficiently handle this slurry for direct use as manure or composting with crop residues.

Conclusions

Production of bio-fuel from plant materials is a major step toward harnessing one of the world's most-prevalent, yet least-utilized renewable energy resources. A breakthrough

through process for converting biomass into bio-diesel fuel promises a cheaper way to go green (Biswas et al., 2003). In this regard, the efficient utilization of press cake of *Jatropha* is necessary for complete economic exploitation of *Jatropha*. Based on the composition and C:N ratio (carbon: nitrogen), it was procured that it can be used for producing biogas. It was found that alternative feedstock generate biogas much faster than conventional feed of cattle dung (Medors, 2007).

It can be concluded from the study that it is a unique and novel approach wherein *Jatropha* defatted waste is used for biogas production, an efficient renewable fuel thereby allowing its safe disposal. Also its effluent slurry provides good organic manure with rich manurial properties. The lab study reveals that a combination of 75% cattle dung and 25% *Jatropha* oil cake (T_4 treatment) gives best results. In fact, *Jatropha* oil cake has enhanced biogas production up to about 25%. The results also reveal the possibility of preparing micro and macro biogas plant fed solely by *Jatropha* in the betterment of mankind to elaborate technology.

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