

Utilization of Different Co-Substrates With Paddy Straw for Enhancement of Biogas Production



Biological Science

KEYWORDS : Paddy straw, cattle dung, bio digested slurry, Biogas

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ABSTRACT

Biogas is being produced in the world since Second World War. However, history of biogas in India goes back to 1931, when a biogas plant was set up in IARI, New Delhi. Traditionally, biogas is being produced from cattle dung only. But nowadays, potential of other substrates is being explored. Paddy straw is one of the richest lignocellulosic waste available in India, which can be utilized for biogas production. This study involves a 120 day trial on production of biogas using paddy straw, bio-digested slurry, cattle dung mixed with water. In this five digesters of 2 litre capacity each, were set up using different ratios of these co-substrates with paddy straw. Comparing the overall production of biogas, after 120 days maximum gas was produced in paddy straw which was soaked for 24 hrs before incubating it. This gave 38,095 ml of gas followed by 37,505 ml of gas produced by combination of cattle dung and water mixed in 1:1. The study concludes that chopped paddy straw along with bio-digested slurry (BDS) gives better biogas production than powdered paddy straw mixed with BDS i.e. 35,920 ml as compared to 34,665 ml, respectively. Effect of temperature and incubation period was also studied. The biogas production is maximum at 80 day incubation, after which it starts decreasing. Temperature when increases, leads to increased production of biogas.

Introduction

The supply and consumption of energy are very important for the evaluation of a nation's development and the standard of living of its inhabitants. The total consumption of energy is increasing day by day. Thus, the sustainable management of natural resources and the development of new and alternative sources of energy is the topic of concern mainly due to slow economic growth. Utilization of waste biomass is considered as a solution to this concern and development in this field has been seen in different developing as well as industrialized countries. In India, Paddy straw is an important agricultural residue, which is considered as waste after the processing of crop. Bioconversion technology plays an important role for the effective utilization of this substrate. Anaerobic digestion can convert the stored energy of this biomass into biogas. But for the effective utilization, it needs to be pre-treated by chemical, thermal and biological means (Vigil *et al.*, 1993). Pretreatment increases the biodegradability of the lignocellulosic biomass. Most of these pretreatment processes require high energy input, or are non-profitable economically, e.g: enzymatic treatments, thus increases the cost of process. Biologically paddy straw, composed mainly of lignocellulose, can be transformed into renewable energies, such as biogas and ethanol, by anaerobic digestion (Chandra *et al.*, 2012b). Biogas can be produced from paddy straw by anaerobic fermentation using cattle dung as a source of inoculum. Biogas generation involves consortium of microorganisms which is a group of hydrolytic, acidogenic and methanogenic bacteria. Hydrolytic bacteria degrade the complex organic matter (carbohydrates, proteins and fats) into simpler forms (sugars, amino acids, fatty acids and glycerol). Acidogenic bacteria breakdown these simpler forms (sugars, amino acids, fatty acids and glycerol) into CH_3COOH , H_2 and CO_2 which is further utilized by methanogenic bacteria to produce biogas. Biogas production is basically a biological engineering process in which a complex set of environmentally sensitive micro-organisms are involved. It is mixture of CH_4 (50-60%), CO_2 (30-40%), H_2 (1-5%), N_2 (0.5%), CO , H_2S and water vapours. Biogas thus produced is a good waste management technique as the anaerobic treatment in this eliminates the harmful micro-organisms. Biogas technology ensures the individual energy unit to fulfil the needs of a family. The by product digester slurry has also fertilizer value, claimed to double the crop yield.

Refined biogas does not add to global warming by burning. The cattle dung used in this has high nitrogen content. It has been observed to be the best suitable material for high yield of biogas due to its pre-fermentation in the stomach of ruminant. To start the digestion of paddy straw extra methane producing microorganisms is needed. Thus, the inoculums should be having active microbial consortium, needed for anaerobic digestion. For this, digestate of already working biogas plants can be used for inoculums (Bayane and Guiot, 2011; Elbeshbishy *et al.*, 2012; Li *et al.*, 2011; Suwannopadol *et al.*, 2011; Zhou *et al.*, 2011)

This study showed that paddy straw which abounds everywhere and is usually burnt off constituting nuisance to the environment would be a very good feedstock for biogas production. It also indicates that mixing paddy straw with cow dung or digested biogas slurry gives sustained

gas flammability throughout the digestion period of the waste since digested biogas slurry acts as a good starter for poor biogas producing wastes. Generation of biogas from this residue upholds the concept of waste to wealth in enhancing sustainability of development. Thus in this work utilization of different co- substrates with paddy straw for enhancement of biogas production was evaluated. Waste paddy straw was chosen as the main substrate and cattle dung and cattle dung slurry was used as co-substrates for comparative studies. It involves a 120 day trial on production of biogas using paddy straw, bio-digested slurry, cattle dung mixed with water. The biogas production was treated as main indicator. Water displacement method was used for evaluating the biogas production.

Materials and Method Inoculums and substrate

The Paddy straw was procured from the Research field of School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana after harvesting of the crop in the month of October and November. It was used in two forms: chopped into 2-5 cm size and powder form. Chopping was done with a Toka machine and was powdered using an electrical grinder. Chopped and powdered paddy straw was air dried at room temperature and stored in polythene bags. Cattle dung was procured from the dairy farm of Guru Angad Dev Veterinary and Animal Sciences Uni-

versity, Ludhiana and was used as inducer for biogas production from paddy straw. Digested cattle dung slurry was procured from a working biogas plant in biogas field laboratory of School of Energy Studies for Agriculture, Punjab Agricultural University, Ludhiana. To maintain freshness and microbial activity, it was stored at 4 °C and reactivated at 37 °C for 2 days before use. All the chemicals used for chemical and proximate analysis were of analytical grade and were purchased from Hi-Media, Loba-Chemicals and S.D. fine chemicals Pvt. Ltd.

Experimental set up

Paddy straw, cattle dung and digested biogas slurry were put in batch digesters. Glass bottles (2 litres) with a working volume of 1.8 litre and 0.2 litre head volume, were used as bioreactors. Five such digesters were set up having composition: cattle dung: water (1:1), Powdered paddy straw: Bio Digested Slurry: Cattle dung (2.5:2.5:1), powdered paddy straw: Bio Digested Slurry (1:1), Paddy Straw Powder soaked overnight and Chopped Paddy Straw: Bio Digested Slurry (1:1). These reactors were closed with rubber stopper and were sealed using wax. Every stopper contained glass tube having their other end into another glass bottle for the collection of gas. Gas collecting bottles were filled with water and another glass tube was fixed into them for the displacement of water by gas into a third bottle. All these five set ups were placed at room temperature and were digested for 120 days in a temperature variation of 20-45 °C.

Analysis of biogas production

Biogas production was measured using water displacement method i.e. by measuring the amount of water displaced by the gas produced in milli litre. The biogas production for each reactor was measured after every fifteen days and level of water was maintained in gas collecting chamber. The digested cattle dung slurry was used as inoculum. The mixture was properly mixed and initially analyzed for pH, total solids, volatile solids, cellulose, hemicellulose, lignin and silica by standard methods by AOAC (2000).

Results and discussion

Proximate and chemical analysis of paddy straw: Table 1 summarizes the characterization of the paddy straw, cattle dung and digested biogas slurry. All the three substrates were oven dried and proximate and chemical composition was analyzed. Results from Table 1 indicate that pH of paddy straw was 8.1 while that of cattle dung and digested biogas slurry was 6.97 and 7.03, respectively. The total solids were more in paddy straw (25.2%) than in cattle dung(15.0) and digested biogas slurry(5.0). The cellulose and hemicelluloses content of paddy straw is higher than that of both cattle dung as well as digested biogas slurry. But amount of lignin is more in digested biogas slurry. Silica amount is also higher in paddy straw that is why it needs to be pretreated in order to decompose it fully. Due to such composition, moisture is required for solid state fermentation of biomass by addition of digested biogas slurry as well as water. These co-substrates helps in adjusting the solid content of the mixture. Lignocellulosic biomass having high cellulose and hemicelluloses are good for bio-conversion technology i.e. anaerobic digestion and alcoholic fermentation. High cellulose also favors the use of biomass for paper and board production (Jain, 1997). According to Elijah *et al* (2009) the rice husk contains: Crude protein, 1.7 - 7.26%; Crude fat,0.38%; Nitrogen free extract, 24.70 - 38.79%; Crude fiber, 31.71 - 49.92%; Ash, 13.16 - 29.04%; Pentasans 16.94 - 21.95%; Cellulose 34.34 - 43.80%; Lignin 21.40 -46.97%.The high amount of lignin results in

resistance to enzymatic degradation.

Biogas production profile: Table 2 shows the biogas production data over the period of 120 days using different co-substrates with paddy straw along with temperature profile. Comparing the overall production of biogas, with retention period of 120 days, maximum gas was produced in paddy straw which was soaked for 24 hrs before incubating it. This gave 38,095 ml of gas followed by 37,505 ml of gas produced by combination of cattle dung and water mixed in 1:1. The study concludes that chopped paddy straw along with bio-digested slurry (BDS) gives better biogas production than powdered paddy straw mixed with BDS i.e. 35,920 ml as compared to 34,665 ml, respectively. Effect of temperature and retention period was also studied. The biogas production is maximum at 80 day retention period, after which it starts decreasing. Temperature when increases, leads to increased production of biogas. Optimum production of biogas is from 30-42 °C. A significant variation in biogas production was observed over the mentioned period. This variation may be due to the fluctuation in digester and atmospheric temperature. Sardar Patel Renewable Energy Research Institute (SPRERI) also reported to have produce 340-450 litre biogas / kg rice straw through thermophilic consortium utilization (Anonymous, 2006), however, when the experiment is conducted at mesophilic temperature without using thermophilic consortium, the biogas production get reduced. The temperature affects the rate of digestion due to the direct contact of digester walls with the atmosphere, which absorb or loose heat depending on the temperature gradient between the digester and its immediate environment. This means that the seasonal variation affect the rate of heat gain or loss from the digester which then affects the microbial activities in the digester. Long retention time and moderate gas production is noticed in 30-40 °C range. A study of biogas production from co-digestion of a 60:40 wt % of cattle dung and sinews gave a maximum biogas production of 3.3 L/day at 33 days after a 20-day period of inactivity (Pualchamy *et al.*, 2008). Saev *et al.* (2009) also reported a period of 20 days of minimal biogas production in their study of co-digestion of wasted tomatoes and cattle dung. The long retention period is may be a result of the complexity of biodegradation involving a high content lignin material present in rice husk. Consequently, the cumulative biogas production increased in a step-wise fashion due to the periods of inactivity between the periods of production. Gadre *et al.* (1990), from their investigation of the optimum time for the production of biogas from cow dung reported that 15 days retention time was the best for maximum production of biogas from cow dung. They attributed the poor performance at low retention times to accumulation of volatile fatty acids and opined that at retention times greater than 15 days, the digester components were under-utilized. Again, the presence of rice husk for the purpose of co-digestion may be responsible for the variation in optimum retention times observed. Hansen (2007) reported that using 100% cow dung under the same condition of temperature and retention time (of 38 days), the cumulative biogas yield would be 26 ml/g total solid. This wide difference may suggest that there was no contribution of biogas production from rice husk.

Conclusion:

This study concludes that paddy straw, which is considered as a waste, is one of the richest lignocellulosic wastes available in

India, which can be utilized for biogas production. The production can be enhanced by using it along with some quantity of cattle dung as well as digested biogas slurry, which acts as a microbial source to pretreat the paddy straw and decompose it better. General chopping of the paddy straw can also effect the production of biogas. Variation in temperature and prolonged incubation also affect the production of gas. As per this study, the biogas production is maximum at 80 day incubation, after which it starts decreasing. Paddy straw, cattle dung and slurry are always available in our environment and thus can be used as a source of biogas, if managed properly. The study reveals further that paddy straw mixed with other substrates is a great potentials for generation of biogas and its use should be encourage due to its early retention time and high volume of biogas yields.

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Table 1. Proximate and chemical analysis of different co-substrates

Parameter	Paddy Straw	Cattle dung	Digested biogas slurry
pH	8.1 ± 0.56	6.97 ± 0.39	7.03 ± 0.24
Total solids (T.S%)	25.2±0.13	15.00 ± 0.56	5.00 ± 0.15
Volatile solids (V.S %)	81.4±0.07	84.00 ± 7.23	66.67 ± 3.41
Hemi cellulose	26.8±0.22	20.40 ± 0.42	7.40 ± 0.26
Cellulose	39.0±0.12	23.60 ± 0.53	14.80 ± 0.44
Lignin	7.0±0.12	10.80 ± 0.34	19.80 ± 0.16
Silica	12.0±0.06	9.40 ± 0.29	9.20 ± 0.29

*Values in ± indicates the standard error of data in triplicate

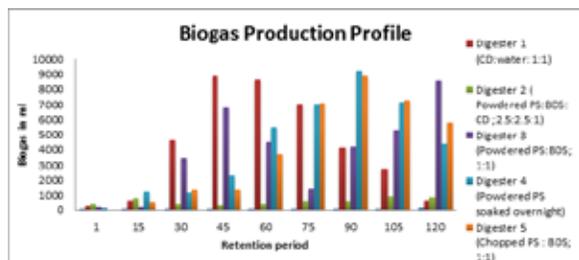
Table 2: Biogas production data over the period of 120 days using different co-substrates with paddy straw

Period of production (Days)	Biogas Digester 1 (ml)	Biogas Digester 2 (ml)	Biogas Digester 3 (ml)	Biogas Digester 4 (ml)	Biogas Digester 5 (ml)	Temperature (°C)
1	270	408	170	120	0	20
15	635	790	213	1270	500	23
30	4620	380	3470	1190	1370	30
45	8860	320	6780	2265	1370	32
60	8620	412	4530	5460	3720	35
75	7000	556	1456	7050	7060	38
90	4130	592	4170	9250	8870	42
105	2720	930	5325	7140	7250	43
120	650	860	8550	4350	5800	44
Total Biogas	37,505 ml	5,248 ml	34,665 ml	38,095 ml	35,920 ml	

Composition of Digester 1: CD:W ; 1:1, Digester 2: Powdered PS :BDS: CD ; 2.5:2.5:1, Digester 3: PPS:BDS; 1:1, Digester 4: Powdered PS soaked overnight, Digester 5: Chopped PS : BDS; 1:1

*PS: Paddy Straw, BDS: Biodigested Slurry, CD: Cattle Dung, W: Water

Fig. 1: Comparative analysis of biogas production using different co-substrates



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