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Full Length Research Paper

Production of biogas by the co-digestion of cow dung and crop residue at University of the Punjab, Lahore, Pakistan

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Anaerobic co-digestion is one of the most promising auxiliaries for treating waste because of the high energy redemption. Bio-digester is designed and apparatus installed for anaerobic co-digestion of cow waste with crop residue in order to manufacture biogas. Gas production is measured by using water displacement method. The experimental results show that 1 kg of cow dung can produce about 15 to 30 L of biogas per day. By the addition of wheat straw, it yielded 20 to 60 L per day of gas. Bio-digester slurry consists of a blend of cow dung, crop residue, and inoculum in the ratio of 50:30:20 (50 kg cow dung: 30 kg wheat straw: 20 kg inoculums) by weight. Experimental analysis for measuring the different parameters affecting the processes like chemical oxygen demand, temperature and pH levels was carried out. Semi-flow through process was applied throughout the process of production in order to manage feedstock and effluent. The University of the Punjab annually produces 1670 kg/acre of crop residue and 1946 kg/day of cow dung, whereas, the total crop produce is 4130 kg/acre/annum. The result shows that by effectively utilizing the crop residue which is available seasonally as 20 to 60 L of bio gas yield per day, this can provide methane gas to laboratories of Punjab University.

Key words: Bio-digester, anaerobic, co-digestion.

INTRODUCTION

Pakistan generates 65% of its GDP from agriculture sector (Siddiqui, 2004). Agricultural country like Pakistan can resolve its energy crisis especially the shortage of electricity and gas by shifting towards renewable energy resources instead of using non-renewable resources like coal. This technology will be helpful in rural sites rich in animal and agricultural waste. Biomass fuel contributes to 30% of Pakistan's prime energy source (Tahir et al., 2017; URL-1, 2017). Biogas is defined as a "mixture of methane and carbon dioxide produced by feeding animal dung (especially the manure of buffaloes, cattle, and sheep) and water into an airtight underground tank, known as a digester and allowing it to decompose" (McKendry, 2002). Production of biogas is a low cost technology and economically feasible, as well as it is environmental friendly. One of the benefits of biogas is that it does not produce air pollutants, such as CO, NOx, SO_2, particulates, and volatile compounds (Tahir et al.,

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2017; Gadi et al., 2003). Recently in Pakistan, Sui (CH_4) gas shortages opened the door for biomass energy which is environmentally sustainable and its use as a by-product/waste application, that is, bio-fertilizer/bio-slurry/nutrient fertilizer/organic amendment due to its nitrogen-rich quality (Menardo et al., 2012; Gupta et al., 2007; Tambone et al., 2009). Jacob (2009) describes that biogas consists of methane (CH_4) and carbon dioxide (CO_2) and formed from the anaerobic decomposition of bacteria's present in the organic compounds. Some of its properties include colorless and odorless gas with a boiling point of -162°C and burns with a blue flame. Methane (77 to 90%) is present in the natural gas. The density of biogas is 1.15 kg/m^3 and the upper calorific value is 39.8 MJ/m^3 which equals to 11.06 kWh/m^3 in electricity units.

The combination of biomass like cattle dung, bagasse, rice husks, grass fodder, sugarcane residue, oat straw, and organic fractions from kitchen waste/food waste in the anaerobic digester in biogas plants for making methane generation will be highly efficient. Biogas is unique renewable energies, because of its characteristics of using, collecting and monitoring organic wastes, fertilizer production and slurry use in agricultural irrigation. In Pakistan, there are about 3 million cows/buffalos, each cow has the capacity to produce 24 kg of manure daily. As 1 kg of cow dung produces 0.5 m^3 of biogas daily, so there is a potential of 1.2 million m^3 per day of biogas, hence, 4.32 million m^3 of biogas per annum (Latif et al., 2008; Naveed et al., 2008). Another report shows that 225,000 tons of crop residue and 1 million tons of animal waste is produced per day in Pakistan. 8.8-17.2 billion cubic meters of gas per year is yielded. “A family size biogas plant with 4 cattle’s producing 4400 kg of dung produces an average of 2200 m^3 biogas per annum”. According to the study conducted at one of the rural areas in Faisalabad city of Pakistan, 10 m^3 plant size were considered ideal because it fulfils the cooking needs of an average family (Tahir et al., 2017).

The objectives of this study are: 1) Production of biogas from cow dung and wheat straw, 2) finding favorable ratios of cow dung and wheat straw for co-digestion, and 3) determining the annual availability of biomass in Punjab University per year.

MATERIALS AND METHODS

This experiment was conducted in the biology laboratory of University of the Punjab on a lab scale. 100 L capacity plastic drum cover with an insulating sheet with two holes one for waste input and second for effluent (output pipe) was made. A gas outlet nozzle was installed. The angle of the outlet pipe was set at 45° so that decomposed matter can easily come out and the drums remain filled to 70% capacity. The daily dosing of sample serves the purpose of an agitator as it moves the digested material out with pressure. The drums were setup after applying adhesives/glue at required position on the drum. Water displacement gallons were attached with the digester through a gas pipe. The slurry added in the bio-digester was a blend of cow dung and crop residue crushed into 0.1 to 1 cm in length (Menardo, 2012). The ratio taken was 50:30:20 (50 kg cow dung: 30 kg wheat straw:20 kg inoculum (which is the gutter waste collected from campus sewage). 50% tap water was added and mixed thoroughly until a homogeneous mixture was obtained. The bio-digester was filled up to 70% capacity with prepared slurry. The inoculum was added to speed up the reaction which is sludge obtained from sewage/gutter of college. The 30% place in digester was left empty for gas accumulation. The drum was air tight so that the anaerobic conditions can develop inside the drum. This study examines up till 30 days to obtain biogas. The gas produces were measured every day by water displacement technique. The optimum temperature is room temperature at the laboratory where temperature is already optimum. The temperature was measured daily by thermometer (model 2014, made in China). pH was measured by pH meter (model 2014, made in China) on regular intervals. Semi-continuous feeding was maintained by adding a fresh feed of 1 kg after 7 days for balancing the ratios of digested material which maintain the biogas yield. The experiment continued for 30 days. For measuring chemical oxygen demand “D1252-06 Test Method A-Macro COD”, by Reflux Digestion, titration method was used. After addition of the first dose of slurry, the apparatus was air tight (Figure 1).

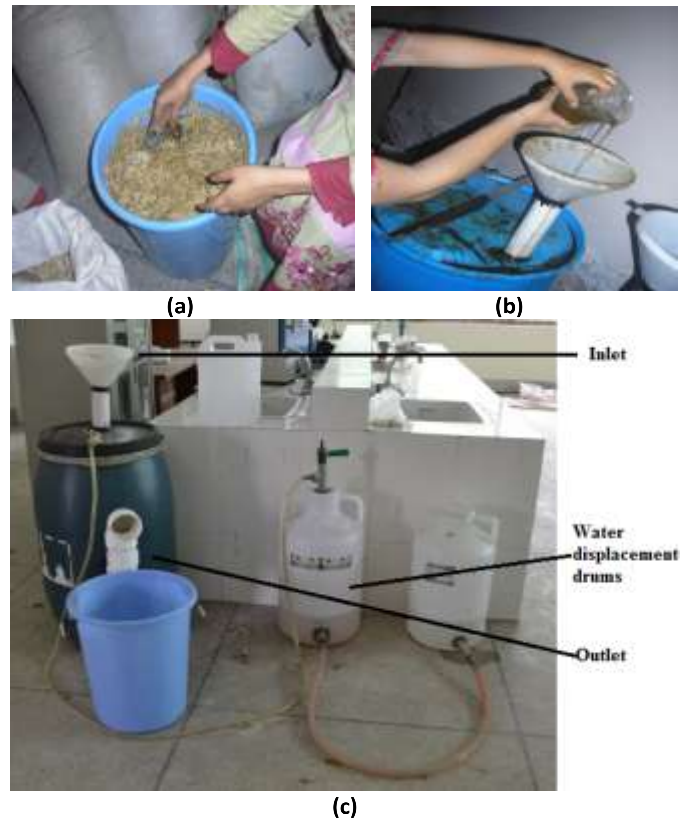

Figure 1. Experimental setup in lab showing the equipment and design.

RESULTS AND DISCUSSION

Biogas (20 to 60 L) was calculated for 30 days using

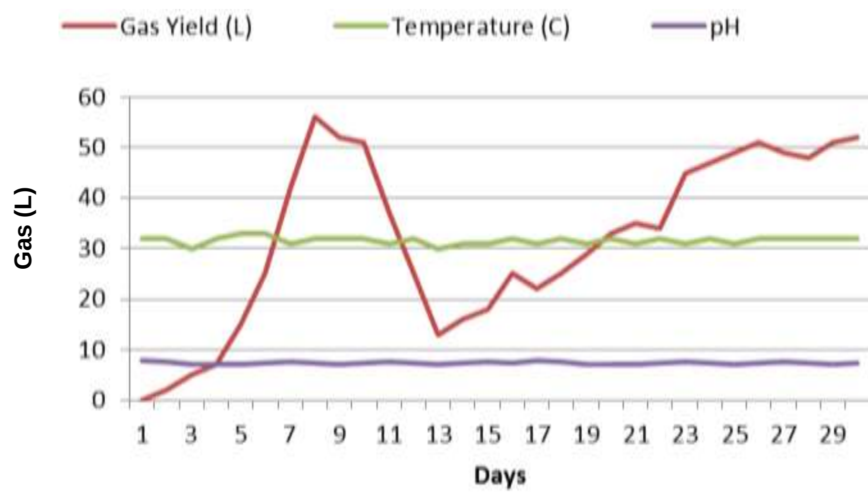

Figure 2. Biogas produce in liters.

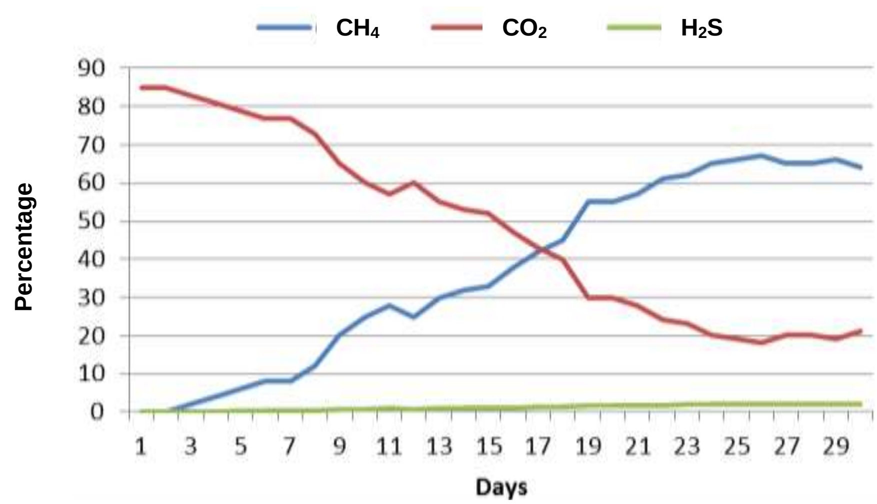

Figure 3. Composition of biogas.

water displacement method. As no noticeable changes occurred in the pH, so no buffer solution was required. pH measured first week is 29.9°C and it fluctuated between 25 and 35°C. Temperature of input slurry is 29.9°C and output slurry is 31°C. Semi-flow through process was followed throughout the experiment.

Figure 2 shows that the biogas production increases during the first 10 days of the experiment then declined but again started increasing. This interval was due to the shift from aerobic condition to anaerobic condition. In the first 15 days, the oxygen present inside the drum was being utilized by aerobic bacteria and this production rate was very fast. Once the oxygen was utilized the anaerobic bacteria starts to dominate and produce gas in anaerobic conditions; this process is comparatively slower than the first one. The first gas from a newly filled biogas plant contains too little methane as measured using water displacement method. So the water drums (marked in liters) attached to methane drum show the changing level of water.

Figure 3 shows the composition of biogas for 30 days. The analysis result shows that in the first 15 days, the CO_2 production rate is 85% because oxygen was present and aerobic conditions were prevailing inside the digester. As the oxygen level goes down slowly, the carbon dioxide production rate also decreases and after 15 days when most of the oxygen is utilized the anaerobic bacteria starts to dominate and it produces

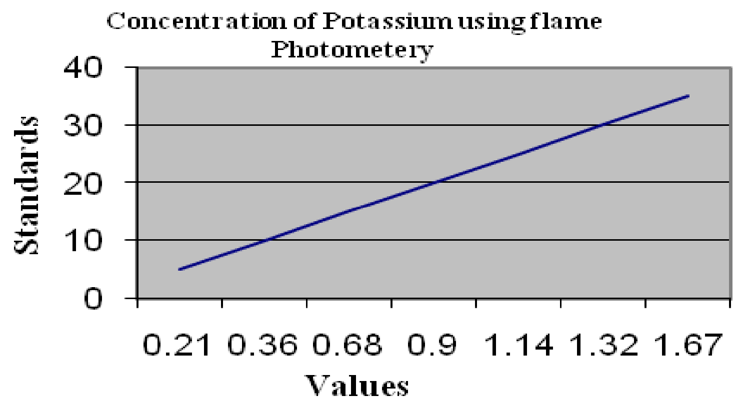

Figure 4. Value of sample for k test.

Table 1. Readings on flame photometer in ppm.

Standards (mg/L)	Readings on flame photometer (ppm)
5	0.21
10	0.35
15	0.58
20	0.9
25	1.05
X (sample)	1.67

methane which is the main component of biogas. Suyog (2011) explains that the digestion process occurring without (absence) oxygen is called anaerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 5200 to 5800 KJ/m^3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable). Hydrogen sulfide (H_2S) which produces 2% is still enough to create big troubles when used in engines/boiler, because it is highly corrosive gas and its small quantities in biogas can eat up the iron made parts of machinery. So elimination of this gas prior to its use in generators is essential. Chemical oxygen demand calculated is 6400 mg/L. Using moisture content formula: Moisture Content (M.C) = wet wt. - dry wt. × 100/wet wt. 89.79% of the moisture content was calculated. In Figure 4 and Table 1, the experiment on flame photometry shows that a significant amount of potassium is present in the slurry; that is, it will be helpful for the plants with potassium deficiency in the soil. The minimum reading of 5 mg/L obtained is 0.21 and maximum of 25 mg/L obtained is 1.67. Hassan et al. (2003) observed the increase in biogas and methane production with plant residues by two fold which was the highest in Lantana supplementation with respect to cow dung. The result of his experimentation suggested that "lantana slurry gave 63.6% methane in the biogas, whereas apple leaf litter contains 59.6%, wheat straw contains 58% and peach leaf litter contains 57.7%, against cattle dung which is 56.1%. The digestion efficiency in terms of biogas release per gram of dry matter with pretreated plant residues was 341 to 372 ml g^{-1} and 31 to 42% higher than cattle dung."

Estimation of cow dung, crop residue and cost analysis

The total numbers of cows are 668 in total agricultural/range land of Punjab University. The average cow dung production is 20 to 22 kg/acre. So, total number of cow dung produce = (22×668) =1946 kg/day. The wheat straw extracted during wheat production in Punjab University is 200 kg/acre and wheat yield/acre is 1400 kg/acre (Table 2). Anaerobic co-digestion of grass silage, sugar beet tops, and oat straw with cow manure evaluated in semi-continuously fed laboratory continuously stirred tank reactors (CSTRs). "It showed that it is feasible with up to 40% VS of crops in the feedstock. The highest specific methane yields of 268, 229, and 213 CH_4 kg^{-1} VS added in co-digestion of cow manure with grass, sugar beet tops and straw, respectively,

Table 2. Cost analysis of the experimental design in Pakistani rupees and dollars.

Items	Quantity	Unit price	Cost
Drum	1	3000	3000
30 L +25 L gallon	2	750	1500
Gas +water pipes and plastic pipes	1	-	2000
Magic epoxy glue	2	150	300
Gauges (2) + valves	6	-	600
Total	7400 Pkr/70$ Us Dollar		

were obtained when the feed is with 30% of crop in the feedstock. Compared with that in reactors fed with manure alone at a similar loading rate, volumetric methane production increased by 65, 58 and 16% in reactors fed with 30% VS of sugar beet tops, grass, and straw, respectively, along with manure. After doubling the OLR from 2 to 4 kg VS m^{-3} day^{-1} less methane was extracted per added VS, leading to a 16 to 26% decrease in specific methane yields, thus leaving more untapped methane potential is being left in the residues" (Torey at el., 2005).

Conclusion

Punjab University can use this biomass to produce gas. 1 m^3 of biogas can produce enough electricity to burn 1.6 units of electricity. So besides supplying methane to laboratories of department, it can be potentially used for electricity generation. By this experiment, it is shown that co-combustion of crop residue and cow dung with the help of slurry from biogas digester is readily available. It is concluded that 1 kg of cow dung can produce about 15 to 30 L per day of biogas. By the addition of wheat straw, it yielded 20 to 60 L per day of bio gas. The fertilizer produced is better than chemical fertilizer as shown in potassium test. The result shows that the crop residue is available seasonally for running the plant throughout the year and for providing gas to laboratories of Punjab University due to its feasibility and potential for anaerobic co-digestions which was tested.

Abbreviations

GDP, Gross development production; **CO,** carbon monoxide; **NO,** nitrogen oxide; **SO_2,** Sulphur dioxide; **COD,** chemical oxygen demand; **BOD,** Biological oxygen demand; **pH,** potential hydrogen; **ASTM,** American Society for Testing and Materials.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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