ANALYSIS OF BIOGAS PRODUCTION THROUGH ANAEROBICS DIGESTION USING COW DUNG AND VARIOUS CO-SUBSTRATES

by

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Biodegradable waste is a sustainable energy resource. In coming years biogas technology can be very useful worldwide, since biogas can be obtained from biodegradable waste material. This technology is based on waste reduction and also is helpful in the clean-up process of India. In this experiment, we have made single-phase biogas set-ups by using two-liter bottles. The fermentation time of the anaerobic digestion for the efficient use of gas as a fuel is about sixteen days. In our biogas digester set-ups for waste decomposion anaerobic co-digestion process is utilized. The primary feed stock is cow dung, whereas the grass, fruit, and vegetable waste are used as co-subtracts. The pH value was maintained at the range level of 6.5 to 6.9. The output biogas yield was 1.59 ml, 1.28 ml, 1.03 ml, and 0.95 ml, within an approximate period of sixteen days. Biogas obtained from cow dung and grass waste is almost identical as biogas obtained from the experimental set-up 1 (pure cow dung). Main performance characteristics of biogas formation were presented in this paper. In order to analyze a daily biogas formation, the pH value, temperature, and hydraulic retention time were changed in this experiment.

Key words: *cow dung, co-substrates, anaerobic co-digestion, biogas formation, renewable energy*

Introduction

The scarcity of petroleum and coal threatens the supply of fuel throughout the world. Also, the problem of their combustion leads to research possibilities to use new sources of energy, such as renewable energy resources. Solar and wind energy, thermal and hydro sources of energy as well as biogas, are all renewable energy resources. However, biogas is distinct from other renewable energies due to its characteristics of using, controlling and collecting organic waste and at the same time producing a fertilizer used in agricultural production and irrigation. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy. Also, its use and application is very simple. Deforestation is a very big problem in developing countries such as India. Mostly charcoal and fuel-wood are used as fuels, which requires cutting down forests. At the same time deforestation leads to decrease in fertility of land by soil erosion. The use of dung and firewood as energy is also harmful for human health (human well-being) considering the smoke emitted and air pollution. We need an eco-friendly

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substitute for energy. Mankind can tackle this problem (threat) successfully with the help of methane.

It is stated by Sitorus [1], that the highest CH_4 content, around 65%, can be produced by using feed stock of fruit and vegetable waste, with the rate of 20-40 ml/min. Zhang [2] investigated process of kitchen waste recycle, using ferrous salt to produce decarboxylation and to obtain the lowest possible char. Iqbal [3], has made up the anaerobic digestion of kitchen waste to produce biogas and also stated that using biomass fuel in our country can help to reduce deforestation, and emission greenhouse gases (GHG). Forhad Ibne Al Imam [4] claims that the digestion time and volume of gas production (%) in cow dung is 20-30 days and 46.03%. Yong [5], revealed that due to the anaerobic co-digestion process in which food waste and straw CH_4 production increased from 39% to 149%, reaching 0.392 m^3/kg_{vs}. The total gas production in a liter capacity was 58 m^3/kg_{vs} and 67.6 m^3/kg_{vs}. Venkateshwara Rao [6], in his study claims that biogas is one of the most efficient and effective options among the various other alternative sources of renewable energy currently available, if produced by anaerobic digestion processes in which microorganisms convert complex organic matter into a mixture of CH_4 and CO_2. The anaerobic digestion production is costly compared to other renewable energy source, such as solar and wind energy [6].

Nallathambi Gunaselan [7], claimed said that organic food waste and municipal soil waste (MSW) using anaerobic co-digestion have reported temperature effect is mango peels conversions kinetics is from 35 °C to 28 °C, and then overall CH_4 production and CH_4 was yields around 90% within a 40 to 50 days, food waste and soil waste gives CH_4 heal and greater than 0.31 VS/g and is high quality choice for commercial methane production. Avicenna [8], argues that it seems that in the optimized process, the increase of biogas production is 67.6 ml/min, or 63.4%, and CH_4 concentration requires 43.6 g to set the OLR and NaOH at minimum.

The specific objectives of many research programs was: (1) to optimize the CH_4 gas evolution from the kitchen waste and (2) By conducting a lab scale study to investigate the biogas yield at an anaerobic digestion of the kitchen waste under ambient temperature conditions [9]. Ukpai and Nnabuchi [10] carried out comparative study of biogas production from the cow dung. A forty-five liter capacity metallic prototype biogas plant was constructed at the National Center for Energy Research and Development at the University of Nigeria. Three typical types of waste: cow dung, cow pea, and cassava peeling were used to investigate the anaerobic digestion in generating biogas from. The experiment was batch operated and daily gas yield was monitored 30 days. Ambient and slurry temperature, as well as the pressure, were also monitored and presented. The digester was charged differently. The mesophilic ambient temperatures range was attained within the testing period. The cow dung had the highest cumulative biogas yield of 124.3 l/total mass of slurry (TMS), whereas the pea had 87 l/TMS and cassava peeling within this retention period. During digestion, followed by changes in pH, the highest gas production was obtained at natural pH. In terms of flammability, they became flammable at different periods of time during digestion. The cow pea was favored in terms of volume of flammable gas production of biogas. The gas is typically composed of CH_4 50-70%, CO_2 30-40%, hydrogen 1-10%, 1-3% nitrogen 1-3%, and whereas 0.1% accounts for oxygen, CO and hydrogen. The study has been conducted to determine the optimum biogas and CH_4 yield associated with the co-digestion of cow dung, using different substrates: fruit, vegetable, and grass waste. Additionally, it has been conducted to find out which co-subtract gives the highest methane production when compared to pure cow dung digestion.

Anaerobic digestion

The digestion process occurring without (in absence) of oxygen is called anaerobic digestion (AD), and generates mixtures of gases. The gas produced, mainly CH_4, can give 5200-5800 kJ/m^3 when burned at normal room temperature is viable and environmentally friendly energy source to replace fossil fuels (non-renewable).

Benefits of biogas technologies

Biogas can be utilized effectively for household cooking, lighting or operating with a small engine used for water pumping. It can be used for chafing fodder and grinding flour by using the already known technology. Compared to other biofuels, biogas has several advantages:

– *Renewable energy source*. The current global energy supply is highly dependent on fossil sources (crude-oil, lignite, hard coal, natural gas). These are fossilized remains of dead plants and animals, which have been exposed to heat and pressure in the Earth's crust over hundreds of millions of years. For this reason, fossil fuels are non-renewable resources whose reserves are being depleted much faster than having the new ones formed. Unlike fossil fuels, biogas from AD is permanently renewable, as it is produced from biomass, which is actually a living storage of solar energy through photosynthesis. Biogas from AD will not only improve the energy balance of a country, but it will also make an important contribution to the preservation of the natural resources as well as to the environmental protection.
– *Reduced greenhouse gas emissions and mitigation of global warming*. Utilization of fossil fuels such as lignite, hard coal, crude-oil, and natural gas, convert the carbon stored for millions of years in the Earth's crust, and release it as CO_2 into the atmosphere. The increase of the current CO_2 concentration in the atmosphere causes global warming, as CO_2 is a GHG. The combustion of biogas also releases CO_2. However, when compared to fossil fuels, the main difference is that the carbon in biogas was recently taken up from the atmosphere, by photosynthetic activity of the plants. The carbon cycle of biogas is thus closed within a very short time (from one to several years). Biogas production by AD also reduces emissions of CH_4 and nitrous oxide (N_2O), as well as utilization of untreated animal manure as a fertilizer. The GHG potential of CH_4 is higher than that of CO_2 by 23 folds or 296 folds of N_2O. When biogas displaces fossil fuels for energy production and transport, reduction in emission of CO_2, CH_4, and N_2O will occur, contributing to the mitigation of global warming.
– *Reduced dependency, on imported fossil fuel*s. Fossil fuels have limited resources, concentrated in few geographical areas of our planet. This creates a permanent and insecure status of dependency on the import of energy for the countries outside this area. Most of the European countries are strongly dependent on fossil energy imports from regions rich in fossil fuel sources such as Russia and the Middle East. Developing and implementing renewable energy systems, such as biogas from AD, based on national and regional biomass resources, will increase security of national energy supply and diminish dependency on imported fuels.
– *Waste reduction*. One of the main advantages of biogas production is the ability to transform waste material into a valuable resource, by using it as a substrate for AD. Many European countries are facing enormous problems associated with the overproduction of organic waste from industry, agriculture, and households. Biogas production is an excellent way to comply with increasingly restrictive national and European regulations in this area and to utilize organic waste for energy production, followed by recycling of the digested substrate as a

fertilizer. The AD can also contribute to reducing the volume of waste as well as the cost of waste disposal.

– *Flexible and efficient end use of biogas*. Biogas is a flexible energy carrier, suitable for many different applications. One of the simplest applications of biogas is the direct use for cooking and lighting, but in many countries biogas is used nowadays for combined heat and power generation (CHP) or it is upgraded and fed into natural gas grids, used as vehicle fuel or in fuel cells.
– *Low water inputs*. Even when compared to other biofuels, biogas has some advantages. One of them is that the AD process needs the lowest amount of process water. This is an important aspect related to the expected future water shortages in many regions of the world.

Materials and method

The cow dung was collected from the farm (tab. 1). Fruit waste was collected from Chennai market, whereas vegetable waste was collected from the Vandavasi vegetable and farmer's market (tabs. 2 and 3). The fruit and vegetable waste is grinded by using an electric mixer. The samples were then stored in separate black polyethylene bags.

Table 1. Characteristics of cow dung

Properties	Value
Total solid	59.73
VS/TS [%TS]	81.55
TKN [g/lg/kg]	1.39
TOC [%TS]	39.35
pH	7.50
Lipids	5.50

Table 2. Characteristics of fruit waste

Component	Banana	Citrus limetta	Apple
pH	4.5-5.2	4.1-4.5	3.3-3.9
Fat [g]	0.33	0.30	17.0
Protein [g]	1.03	0.7-0.8	0.26
Carbohydrate [g]	22.24	9.3	13.81
Water [g]	86.32	88.12	85.56

Table 3. Characteristics of vegetable waste

Component	Potato	Tomato	Brinjal
pH	5.4-5-9	4.3-4.9	6.0
Fat [g]	0.10	0.20	0.18
Protein [g]	2.0	0.90	0.98
Carbohydrate [g]	17.0	3.9	5.88
Water [g]	75.0	94.5	25.0

This anaerobic digestion is a condition of mesoplics (35 °C). The daily biogas production was measured by using a wet tip gas meter and the biogas components (CH_4, H_2O, CO_2), which were measured weekly, by using of Hatch Carle 400AGC gas chromatograph. The pH value was measured by a pH meter. The temperature was measured by a digital thermometer.

Experimental set-up

This experiment consists of a small scale lab set-up with four numbers of two-liter bottles which are used as digesters. Different concentration and combination of waste is used here. Different parameters of input and effluent are measured, such as the total solid, volatile solid, volatile fatty acid, pH as well as the temperature, nitrogen, carbon, and phosphorous. The experiment consists of four set-ups, figs. 1 and 2:

- Experimental set-up 1 consists of a two-liter bottle containing 50% of cow dung and 50% of water.

- Experimental set-up 2 consists of a two-liter bottle containing 50% of (cow dung + grass) and 50% of water (tab. 4).
- Experimental set-up 3 consists of a two-liter bottle containing 50% (cow dung + fruits waste) and 50% of water.
- Experimental set-up 4 consists of a two-liter bottle containing 50% (cow dung + vegetable waste) and 50% of water.

Table 4. Characteristics of grass waste

Properties	Value [11]
pH	4.3
Volatile fatty acids [gkg^{-1}DS]	5.3
Ammonia [gkg^{-1}DS]	46.18
Volatile solid [VS) [%]	92
Dry solid (DS) [%]	30.66
Water soluble carbohydrates [gkg^{-1} DS]	49.83

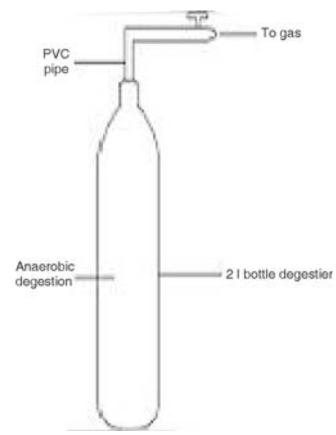

Figure 1. Single phase anaerobic digester model

Figure 2. Experimental set-ups (lab scale)

Experimental results and discussion

Experimental results are presented for all four experimental set-ups on tabs. 5 and 6, and on figs. 3-5.

The results presented on fig. 3 clearly indicates that the gas production in set-up 1 is on the increase when compared to other set-ups. The next highest gas production points to the set-up 2 containing cow dung and co-substrate grass waste.

This graphs shows that the pH is on the higher side, whereas the reaction inside the bottles continues. It starts decreasing and after day eight, it becomes acidic. Consequently, upon shaking the bottle, the pH increases. The production rate of biogas depends on the pH maintained.

This graphs shows the difference between the total solid concentration and digestion time. Therefore, according to the graphs, presented previously we can understand the variation of total solid concentration on a daily basis.

Table 5. Biogas production in ml

Experimental set-up /days	2nd	4th	6th	8th	10th	12th	14th	16th	Average
Experimental set-up 1	0.89	0.82	0.85	0.97	1.56	1.90	2.73	2.95	1.59
Experimental set-up 2	0.40	0.90	0.65	0.72	1.43	1.54	2.06	2.51	1.28
Experimental set-up 3	0.31	0.63	0.45	0.61	1.15	1.40	1.60	2.05	1.03
Experimental set-up 4	0.29	0.52	0.42	0.48	0.99	1.35	1.58	13.99	0.95

Table 6. The pH and total solid concentration

Days	Experimental set-up 1		Experimental set-up 2		Experimental set-up 3		Experimental set-up 4	
	pH	TS%	pH	TS%	pH	TS%	pH	TS%
2nd	7.13	0.412	6.03	0.452	6	0.325	6.1	0.325
4th	7.01	0.432	6.1	0.251	6.05	0.253	6.25	0.235
6th	7.32	0.653	6.01	0.251	5.6	0.475	7.4	0.215
8th	5.03	0.225	7.4	0.426	5.01	0.442	5.3	0.421
10th	6.1	0.441	6.35	0.494	6.53	0.371	6.12	0.214
12th	6.2	0.532	6.5	0.622	6.23	0.521	6.35	0.241
14th	6.2	0.654	7.00	0.691	6.35	0.311	6.25	0.484
16th	6.32	0.685	6.3	0.674	6.65	0.65	6.7	0.412
Average	6.41	0.504	6.42	0.489	6.41	0.401	6.43	0.356

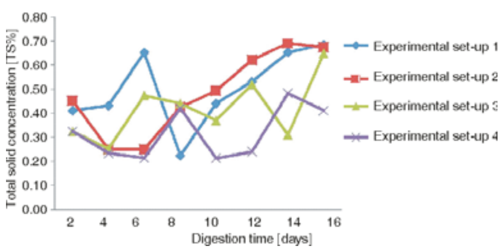

Figure 3. Amount of gas production [ml] for experimental set-ups *vs.* digestion time (days)

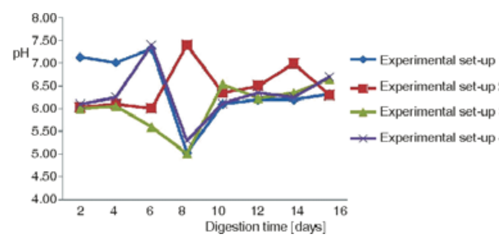

Figure 4. The pH value is obtained for various experimental set-ups *vs.* digestion time (days)

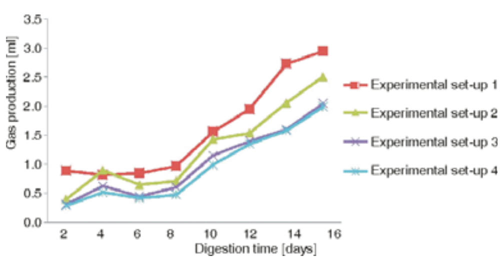

Figure 5. The TS value is obtained for various experimental set-ups *vs.* digestion time (days)

Conclusion

The AD has been demonstrated to be a highly effective process for producing a sustainably alternative energy form of CH_4 production. The study was performed by adding various co-substrates such as grass, fruit, and vegetable waste along with the cow dung under a single phase type. Through the successful anaerobic processing inside the reactor, methanogen gradually converts the organic acids into CH_4 gas and CO_2. The biogas production range from the AD of pure cow dung is 1.59 ml, whereas the cow dung and the co-substrate grass waste types produce 1.28 ml, by using fruit and vegetable waste, it ranges from 1.03 ml and 0.95 ml. The amount of CH_4 increases after the seventh day of the digesting. The pH was maintained at 6.3-6.7 to increase the biogas generation. Thus, the study implies that anaerobic digestion of pure cow dung produces the highest amount of biogas and the cow dung along with the co-substrate grass waste produces the next higher amount when compared to the other co-substrates used in the study. The future aims of this research are to perform the biogas production by using the cow dung and grass waste under two-phase methods on a large scale.

Acronyms

AD	– anaerobic digestion
CHP	– combined heat and power generation
DS	– dry solid
GHG	– green house gas
HRT	– hydraulic retention time
MSW	– municipal solid waste
OLR	– organic loading rate
pH	– hydrogen ion concentration
TKN	– total Kjeldohl nitrogen
TOC	– total organic carbon
TMS	– total mass slurry
TS	– total solid
VS	– volatile solid

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