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Production of Biogas from Anaerobic Digestion of Biodegradable Waste Blends in Lab-scale Reactor

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Abstract

Wet anaerobic digestion of Biodegradable materials is a common practice in production of Biogas. The anaerobic digestion of the blends of Biodegradable materials however gives better result increasing the amount of Biogas production and improving quality of the gas. A movable lab-scale biogas reactor has been developed, which can be setup at any place within small space. It is capable of being used for digesting various compositions of Biodegradable waste blends in a single set-up. The set-up is simple, easy to construct and with help of it, the potential of producing biogas of various biodegradable waste blends can be measured with ease. The data from this experimental set-up can be multiplied to presume results for larger plants with sufficient accuracy. The works using this set-up, the methods of work and the results thus obtained are presented in this paper.

Keywords: *Lab-scale Biogas reactor, Wet Anaerobic digestion, Biodegradable waste blends.*

1. Introduction

Anaerobic Digestion (AD) of organic materials to produce biogas has been a common practice for quite a time. AD is the process of decomposition of organic matter by a microbial consortium in an oxygen-free environment. It is a process found in many naturally occurring anoxic environments including watercourses, sediments, waterlogged soils and the mammalian gut [1].Wet anaerobic digestion being a particular process of the type, in which the feed materials get digested in anaerobic conditions in wet state. Biogas has been used as a source of fuel in countries like India, China, Sweden, Bangladesh etc. Biogas, which is one of the byproducts of anaerobic digestion, comprises of about 60% methane and 40% carbon dioxide [2]. There are many biogas plants in rural areas of Bangladesh where biogas is produced from the feed materials of various types e.g., kitchen waste, cow dung, poultry litter and other waste materials [3]. It was decided to construct a biogas reactor that could be used for determining the potential of various feed materials for producing biogas. Here, potential is mentioned as justification of using a feed material of biogas plant for producing the highest amount of biogas. However, to keep the costs of this research in a limited range, it was decided to construct a lab-scale biogas reactor, which is useful to study the potential of various biodegradable waste blends as feed. The dimensions of the set-up are also kept small to prevent use of excess space. The design and fabrication of the reactors is however modified and dc motor driven agitators have been added to each of the reactor flasks for providing uniform agitation to each of them. The agitators have been constructed according to the requirements. Agricultural wastes are a potential source for biogas production and are used in various regions [4]. Works using plant biomass has been studied by researchers as well, where maize silage, rye grain etc. are used as feed for the plant [5].Effects of various conditions on this type of generation has been studied, for example: the effects of alkaline environment on the production of biogas from agricultural wastes [6].

Biogas production from feed material blends containing paper waste as a constituent however is a less common practice. Work has been done on this idea abroad [7], but it is not very familiar in Bangladesh. It was decided to investigate the possibility to use waste paper in feed composition in the experiment in Bangladeshi environment. Water hyacinth is also an organic compound available in abundant amount, which can be used in the feed material blend [2]. The blend of Cow dung, waste paper and water hyacinth was used as feed in the experiment. The overall objective of the research is to observe the effect of the amount of total solids on biogas production and difference of production in presence and absence of waste paper.

2. Construction of The experimental set-up

The construction of the experimental set-up was done by addition of dc motor driven agitators to chemical reaction flasks used in laboratories. The agitators consisted of dc motors, agitator shafts and impeller blades. The agitator shafts had to be fitted inside a bearing. The bearing was press fitted to a bore holed stop cork. The corking was done for the purpose se to prevent the leakage of gas from the reaction flasks. The motors used for rotating the agitator shafts are 12v dc motors.

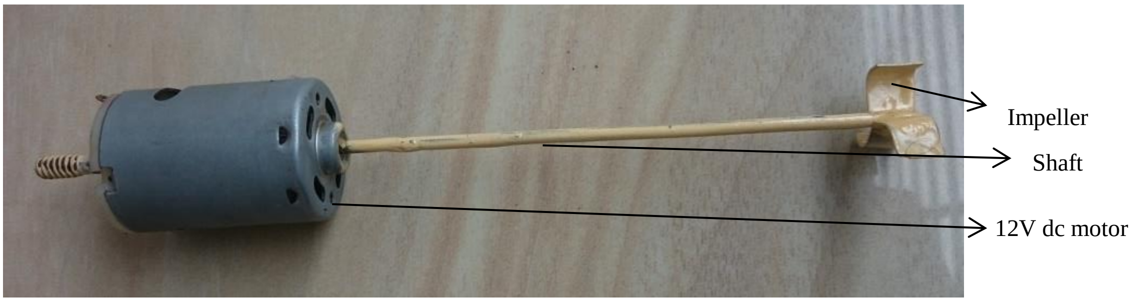

Fig. 1. The dc motor driven agitator shaft

Fig. 2. Biogas reactor set up before addition of agitator

The main set up, which is the biogas reactors were built in a batch of three sets. Each set of the reactor consists of two reaction flasks and one measuring cylinder. The first reaction flask in each set is the reactor flask, in which the blend of biodegradable materials is fed. The other flask is used as water tank, where water is stored at the beginning of the experiment. The flasks and the cylinders are connected with each other using water pipes as shown in **Fig.2.** The set up was corked with stop corks for the purpose of prevention of any leakage of fluids from the system.

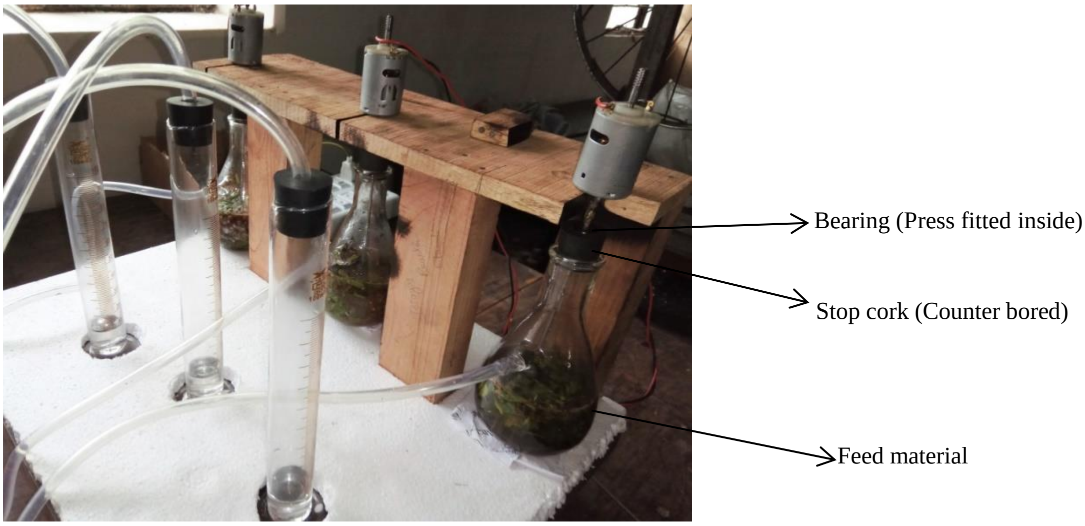

Fig. 3. Biogas reactor set up after addition of agitator

The flasks, the measuring cylinders and the water pipes all are transparent, which adds benefit to the experiment. Any change in the level of meniscus in any apparatus is spotted with ease. The agitator sets were added on the top of the biogas reactor flasks. Smooth rotation of the agitator shafts without displacing the flask was ensured, which was achieved by means of incorporating small ball bearings to the shafts .The bearings supported the load of the agitators and the forces from the rotation of the agitator shafts.

Measurement of Produced gas: The amount of biogas production is measured in water displacement method in the experiment. The reactor flask is connected to the water tank using pipe line, through which gas produced in reactor moves to the tank. The water tank is filled with water at the beginning of experiment. This water is forced out to the measuring cylinder through pipe line under the pressure of biogas produced. The graduated measuring cylinder gives the amount of gas produced directly in mL.

3. Feed materials blending

The feed composition used for the experiment was a blend of biodegradable materials. The blend comprises of: 1.Cow dung, 2.Waste paper, 3.Water hyacinth. Waste paper was selected as one of the feed materials as it is abundantly available in the university campus. The water hyacinth is another constituent of the blend. It was collected from a nearby pond. Cow dung used was sun dried for around 15 days and then it was crushed into powder. All three materials were added in the reactor flasks in 250 mL of water and blended by means of the dc motor agitators sufficiently, so that the blend could be homogeneous. All reactors were given similar nature of agitation. The agitation was provided in the interval of 2-3 days to give enough retention time to the feed materials. The rotational speed of the agitator shaft was always kept between 50-100 rpm. Greater rotational speed was avoided as that would create suction pressure and force some feed material from reactor flask to water tank through the pipe lines.

The composition of the feed in each reactor flask contained the same materials, but the amount of waste paper addition was varied. The reactor flasks were marked by the letters A, B, C. The quantity of the various elements in the various reactors is shown in **Table 1**. The experiment was conducted for duration of 45 days, until the daily biogas production became almost negligible to consider.

Table 1. Feed materials composition

Reactor	Amount of Cow dung(g)	Amount of Water Hyacinth(g)	Amount of Waste Paper(g)	Total amount of solids(g)	% of Cow Dung	% of Water Hyacinth	% of Waste Paper	% of solids in 250 ml water
A	5	5	0	10	50	50	0	3.85
B	5	5	4	14	35.71	35.71	28.57	5.30
C	5	5	8	28	27.78	27.78	44.44	6.72

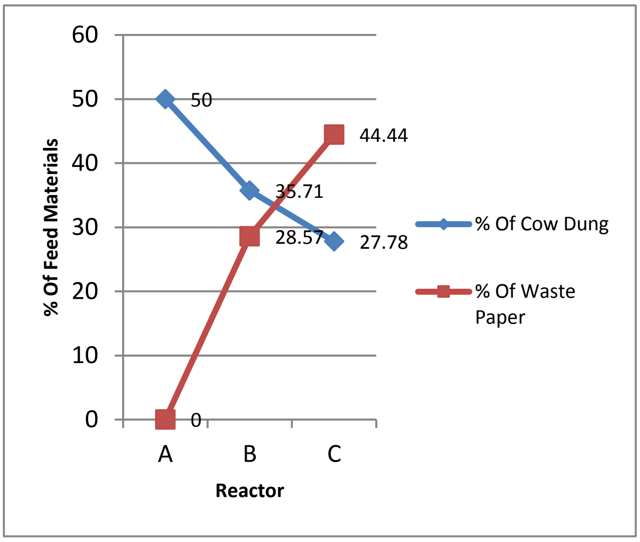

Fig. 4. Feed material percentages in reactors

In **Fig.4,** the percentage of various materials of the feed is presented. The curve for water hyacinth is not shown, as the curve would coincide with the curve of Cow dung, due to both being fed in the same amount in reactors.

The curve represents the percentage of feed materials in each reactor. The curve showing the percentage of cow dung is in gradual decrease. This does not mean that cow dung addition is done in lesser amount in other reactors; rather the waste paper amount is gradually increased.

4. Results

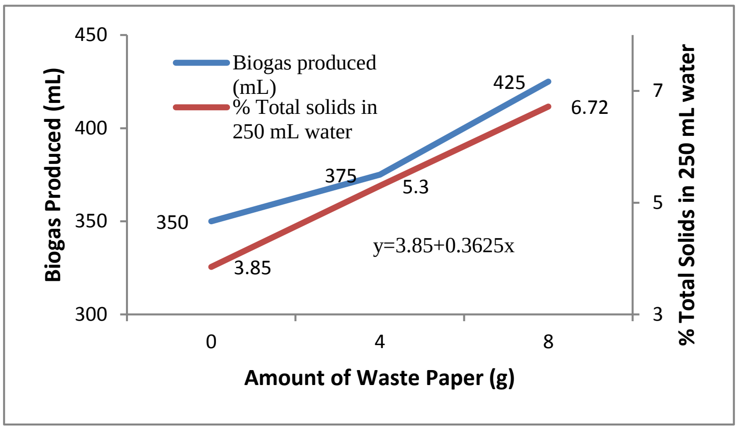

Fig. 5. Relation between biogas production with feed parameters

The reactors with three different compositions produced biogas in various quantities. The relation between produced biogas with the change of composition, the amount of waste paper in each of the reactors and total percentage of solids in 250mL of water solution is given in **Fig.5.** The total solids percentage curve shows the equation,

$y=3.85+0.3625*x$; where,

$y=$ % of total solids in 250 mL water

$x=$ amount of waste paper (g).

Finally after 45 days of retention period, Reactor A produced 350 mL, Reactor B produced 375 mL & Reactor C produced 425 mL of biogas. The condition of the feed blends is shown in the form of pH values in **Table 2.**

Table 2. pH values of Feed materials

Digester	pH- values of feed mixture	
	Before digestion	After Digestion
A	7.18	7.96
B	6.81	7.57
C	6.71	7.35

5. Discussion & Recommendations

The biogas reactors are better to be kept at a temperature slightly above the room temperature. It is important to keep some heating sources to maintain temperature difference between the ambient temperature and the reactor flask during rainy season or damp weathers. The difference of temperature should be 4-5℃ . The heating accelerates the gas producing reaction in mentioned conditions. However, overheating is not a good idea as when the reactors get heated excessively, the water inside the reactor vaporizes causing error to the experiment. Also the heating process is not used in dry days. In many situations, two 100w bulbs can be used, when the ambient temperature is sufficiently low. It is necessary because biogas production rate is best at the temperature of 30-35℃ [3].

In this experiment, the feed materials used are Cow dung, Water hyacinth and waste paper. The set-up is however constructed such a way that wet anaerobic digestion of any other such materials can occur in it. The agitators are sufficiently powerful to blend and agitate small quantity (measured in grams) of materials. The reaction flasks used in this experiment are of good quality and totally leak proof. The experiment should only be conducted in such good quality apparatus. In case of using other biodegradable waste blends as feed , the materials should be crushed or at least be cut into small pieces before feeding in the reactor.

6. Conclusion

The investigation in this experiment finds a positive conclusion that, the use of paper waste to produce biogas is justified. Other parameters and criterion may be experimented to state whether the use of this material in feed is beneficial or not. The lab-scale reactor constructed might be useful to investigate the justification of various other materials of such types testing their potential as a constituent of the feed mixture.

7. References

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