

# Impact of different factors on biogas production in poultry dropping based biogas plants of Bangladesh

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**Abstract:** Bangladesh, with poultry farms number of 215000 and poultry population of 200 million, has a potential of 1.33TWhr electricity per year. Despite of this huge potential, only few number of biogas plants have been deployed till date. Besides, most of these plants are unable to produce the expected amount of biogas as most of the digesters of these plants are made locally and they don't have any scheme for monitoring and controlling temperature, pH, bacterial population in digester, mixture of different substrate, hydraulic retention time, total solid (TS), periodic agitation, periodic loading and unloading of substrate etc. But, there is few bigger size plants which contain imported digesters equipped with monitoring and controlling schemes, hence they produce bigger amount of biogas. In this study, an analysis has been done focusing the impacts of above mentioned factors on biogas production by comparing biogas production between locally made digesters and imported digesters. The result reveals that up to 75% more biogas is generated in imported digesters than the locally made digesters.

**Keywords:** Digester, Anaerobic Digestion, Psychrophilic, Mesophilic, Thermophilic, Hydraulic Retention Time

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## 1. Introduction

In Bangladesh only 3% of the people enjoy the facility of natural gas coming to their homes through pipe lines. The lucky few mostly live in the cities. Most of the Bangladesh's rural people depend on biomass, crop residues, plant debris, animal dung and wood for fuel creating deforestation, flood, soil erosion etc. Women and children, on whom the burden of collecting fuel falls, suffer the most. They are the worst victims [1] of indoor air pollution such as smokes in the kitchens. Biogas technology is one of the best means [2] to provide natural gas to the largest number of rural people. It can provide them with pollution free, efficient energy for cooking and at the same time protect them from diseases by giving them a cleaner environment. Biogas technology can be used to implement a sustainable waste management program suitable for rural areas, as wastes of all sorts are transformed into biogas or slurry. Besides, biogas can be used to produce electricity for poultry farm itself to reduce farming cost as well as household use. According to the Bangladesh Bureau of Statistics (BBS) the number of

poultry farms [3, 4] in Bangladesh was 49825 in 2007-08. Out of which 33225 were broiler farms, 10099 were layer, 227 were hatchery, 5524 were duck and 750 were duck farms. The annual growth rates of those farms were 28%, 18%, 20%, 22% and 9% respectively. According to International Finance Corporation (IFC), the number of poultry farms in Bangladesh is 215000. From the poultry droppings and litter, biogas can be produced [5]. This biogas can be used for daily cooking, lighting or electricity generation. Different poultry birds give different amount of droppings. Hence different amount of biogas is produced from different type of birds [6]. Breeder birds give approximately 245gm of droppings, whereas other birds give around 100gm of droppings per day. Almost thirty thousand tons of droppings are projected to be generated. If all these droppings can be used for generation of biogas then a great amount of energy [7-10] could be produced. The usual solid contents of the droppings are about 20%. Biogas produced from per kg of solid content is about 0.4 m<sup>3</sup>. 1kWhr of electricity can be produced from 22.4 CFT of biogas according to BCSIR. About 82 million CFT of biogas

can be produced per day which is equivalent to 30 billion CFT of biogas per year. These amounts of biogas can produce 3.65 GWhr of electricity per day which is equivalent to 1.33 TWhr per year [9]. For 14 hours of operation this biogas can run a 260MW generation unit. Biogas plant can supply required electricity to the poultry farm itself and to the neighboring localities where national grid power is not available. This will also reduce CO<sub>2</sub> emission, alleviate environmental pollution, bad odor produced in poultry farms, create job scopes for people of the adjacent area, mitigate the stress on the national grid and can generate revenue selling organic fertilizer. Besides, efficient management of produced biogas, electricity and heat wastage will provide the maximum benefit out of the available resources. Despite all these prospects only a limited number of biogas plants are deployed in the poultry farms of Bangladesh. Besides, plants already deployed are not managed properly [11] which reduces the production of biogas hence the efficiency. There are different factors which influence the production of biogas e.g.-temperature, pH, bacterial population in digester, mixture of different substrate, hydraulic retention time, total solid (TS), periodic agitation, periodic loading and unloading of substrate etc. This study is aimed at to reveal the influence of these factors on biogas production in biogas plants deployed in poultry farms.

## 2. Methodology

For technical and economical success insuring stability process and maintaining required quality and quantity of gas is a prerequisite [12]. To maintain these prerequisite following conditions must always be fulfilled:

- Anaerobic condition in the digester must be maintained.
- Temperature must be controlled to the permissible values.
- Availability of nutrients for bacteria;
- Substantial amount of nutrients bacteria must always be present in the digester.
- Substrate must be loaded and unloaded periodically.
- C/N ration must always be observed and work accordingly.
- Correctly chosen proportion of solids content and proper agitation;
- Absence of inhibitors of the digestion process

### 2.1. Temperature

Temperature has the most pronounced impacts on anaerobic digestion. It has three main temperature ranges: from 10-25°C (psychrophilic conditions), from 30-37°C (mesophilic conditions) and from 48-55°C (thermophilic conditions) [13]. Psychrophilic digestion process is very slow hence only mesophilic and thermophilic digestion processes are used in practice. At very low or high temperature the activities of bacteria population is almost

stopped consequently the digestion process is becomes very long. Hence the production of biogas is reduced. The methane content becomes very low. As a result the produced biogas cannot be used as fuel for electricity generation and cooking [12-15].

### 2.2. pH Value

The pH of the digester is a function of the concentration of volatile fatty acids produced, bicarbonate alkalinity of the system, and the amount of carbon dioxide produced. The optimum range of pH for biogas production is between 7.0 and 7.2 [16]. But the substantial biogas can be produced for the pH range of 6.6 to 7.6. Biogas production reduces many fold for the pH value of less than 5 as the bacteria population decrease significantly under the circumstances.

### 2.3. Bacterial Population in Digester

Digester must always contain a certain amount of bacteria for acceptable amount of biogas production. Any dip in bacteria population impedes the production of biogas. Addition of enzymes enhances the bacteria population which in turns increases biogas production [13].

### 2.4. Mixture of Different Substrates

As different substrate produce different amount of biogas, the mixture of them increases the biogas production and methane content [10].

### 2.5. Hydraulic Retention Time (HRT)

The Hydraulic retention time (HRT) is also known as hydraulic residence is the time required for complete digestion of the substrates in Digester. Hydraulic retention time is the volume of the digester divided by the influent flow rate.

$HRT = \text{Volume of Digester} / \text{Influent Flow Rate}$

where using SI Units Volume is in [m<sup>3</sup>] and Influent flow rate is in [m<sup>3</sup>/h]. HRT is usually expressed in hours (or sometimes days).

### 2.6. Total Solid (TS)

Total solid contained in a certain amount of materials is usually used as the material unit to indicate the biogas-producing rate of the materials. Most favorable TS value desired is 8%.

### 2.7. Daily Substrate Input

The daily substrate input depends on the HRT of the digestion process. The HRT can be 10 days to 80 days. If digester HRT is 10 days, than daily substrate load will be 1/10 from the overall volume of substrate in digester. For biogas plants working in thermophilic range, daily substrate load can constitute up to 1/5 of overall substrate volume in digester.

### 2.8. Substrate Digestion Time

Choice of substrate digestion time depends also from the type of substrate used. Cattle substrate takes 10-15 days, pig manure 9-12 days, poultry manure 10-15 days and 40-80 days manure mixed with vegetation waste for complete digestion [14].

### 2.9. C/N Ratio

For optimal C/N ratio different substrates are mixed for which maximizes the production of biogas.

### 2.10. Regular Agitation

For maximizing the production of biogas regular agitation of substrate in digester is required. The regular agitation frees the produced biogas entrapped in the substrate, mixes the fresh substrate with bacteria population, prevents scum and sediment, prevents temperature gradient inside the digester, provides the homogeneous mixture of bacteria population and prevents the formulation of voids.

## 3. Study Area

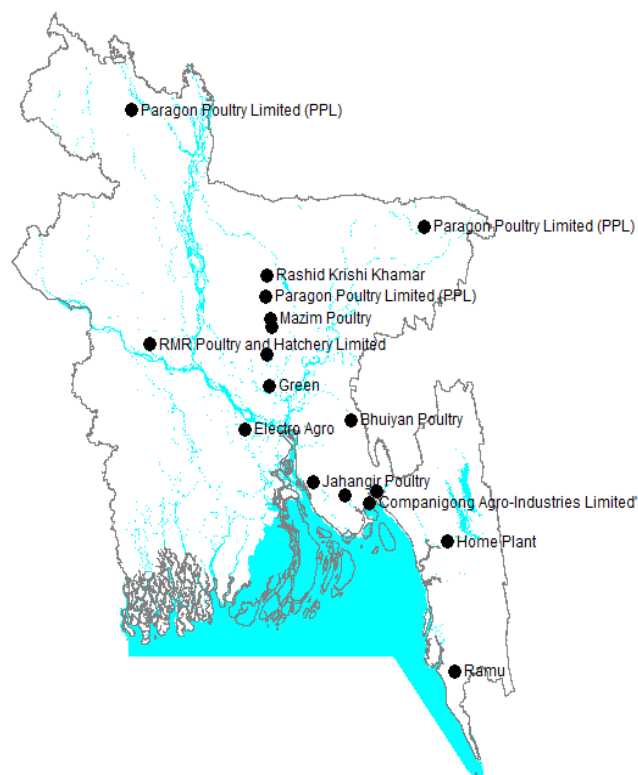
In Bangladesh two types of digesters are used for biogas production in poultry farms [9]. The large portions of these digesters are locally produced and are used for smaller size of biogas plants. But in larger size of plants the digesters are imported from abroad.

Locally produced digesters are made of concrete and are of low costs. But no control system is available for these digesters. Hence they produce less biogas. On the other hand, imported digesters are made of steel, bigger in size and cost higher. But as they have control system for controlling above factors they generate larger amount of biogas.

There are numerous biogas deployed in different parts of Bangladesh. Paragon Poultry Limited (PPL), one of the biggest poultry farms in Bangladesh, has deployed biogas plants at Gazipur, Mymensingh, Rangpur and Sylhet. One plant is ready to operate at Panchagarh also. We have surveyed biogas plants in Gaziupur, Mymensingh and Rangpur, and also collected information about Sylhet and Panchagarh plants. Felix Energy Service (FES), a Danish company for setting biogas power plant, in collaboration with Computerized Service Centre (CSC) of Narayanganj has set up more than 20 biogas plants in poultry farms of different parts of Bangladesh. A few of them has been surveyed and also information has been collected for remainder of them. Local companies and FES have set up the biogas plants; FES and CSC have provided all the equipments. There is another biogas plant set up by individuals in Rangunia, Chittagong for household electricity generation. The plants generate 6.4 m<sup>3</sup> to 4000 m<sup>3</sup> of biogas. Out of 18 (Figure 1) plants first 16 are using digesters with local materials and last two are using imported digesters. One plant is using local equipments which includes generator. 13 are using local equipments and assembled generators. 4 of them are using imported

machineries. Three of them are using 2 generator units. Rests 15 are using 1 generator unit. Table 1 shows the detail of these plants.

Only 3 plants are using mixing tanks, all of them are of PPL. Most of them are using 1 digester, but Rangpur is using 4 digesters and Gaziupur using 2 digesters. Only three are using separate holding tanks and only two of them are using how water tank for temperature control.



**Figure 1.** Locations of different biogas plants in different parts of Bangladesh which are studied

## 4. Results and Analysis

Digesters can be locally built or can be imported. For both the cases the cost for per cubic meter of biogas generation is almost equal. The plant of 1200 cubic meter capacity has a bigger cost because they have designed a bigger size digester for future expansion. For locally converted generators the overall costs remain constant and much smaller than the plants with imported equipments. The generation cost per kWhr of electricity is given by the Figure 2.

The digester cost remains fairly constant for all scale of generation. Generator cost for locally converted biogas generators remain small, but for imported generator the cost is fairly high. Other costs remain fairly constant all over.

The value of pH between 6.8 and 7.2 gives the best production of biogas. Anything outside of this range reduces biogas production. Hence it is very important to maintain the pH. Usually pH of a digester is self-regulating, hence any aberration of it tend to be converged to the reference value

on its own. But there could be cases where pH needed to be controlled if too much deviation is observed. Usually lime water is introduced to the digester to maintain pH.

For locally made digesters there are no arrangements for periodic measurement of pH which could reduce the biogas production but for the cases of imported digesters there are arrangements for periodic pH measurement, but there are no automatic pH control arrangements, hence the onus is fully on the operator to maintain the pH. For this research, biogas plants of Gazipur and Mymensingh have been visited which use imported digesters. The pH is measured and maintained regularly. Note that not every day's pH is tabulated. Only November and December's pH are found and it seen that the pH always remains 7 over the mentioned time (Figure 3).

Temperature of digester is the most important parameter for optimal biogas production. The average temperature over the year varies between 17°C to 30°C. The maximum and minimum temperature can vary over a larger range. But the temperature should remain as close to 38°C as possible for maximum production of biogas (Figure 4).

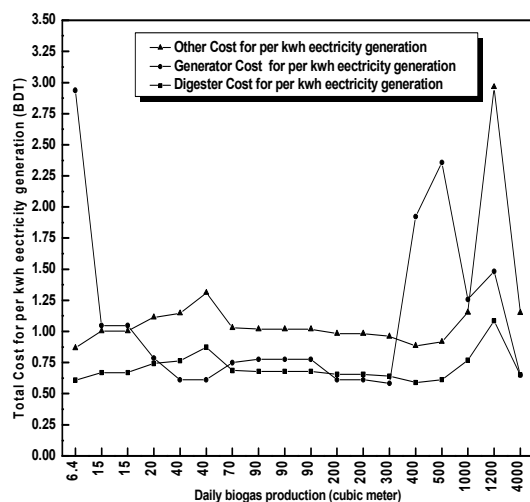


Figure 2. Total Cost for per kWh electricity generation

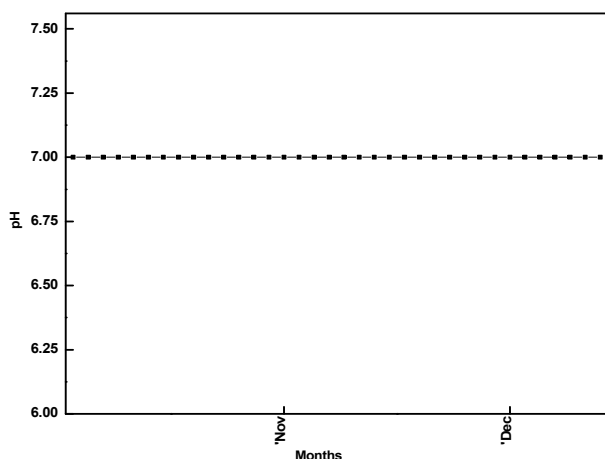


Figure 3. pH of an imported digester over the different months

So if temperature is not controlled the production of

biogas will vary with the variation of temperature. The variation of temperature will reduce biogas yield and methane content of the gas. Hence the air and H<sub>2</sub>S removal unit need to work more time than usual. The running time of generator will be reduced, in turn it will reduce electricity yield. So for rated load it will increase current and reduce voltage, rotational speed and frequency. The energy of cooling water and exhaust gas can be used to control the temperature of the digester. The cooling water of the generator can be directly used to control the temperature of the digester. But this water along is not enough for the digester in an extremely cool weather. Hence the energy of the exhaust gas is used with a heat exchanger for producing more hot water. The cooler the weather the more temperature difference between the input and output of the heat exchanger will be observed. As the imported digesters have the arrangements for temperature control the subsequent figure shows the mentioned parameters for them over the year.

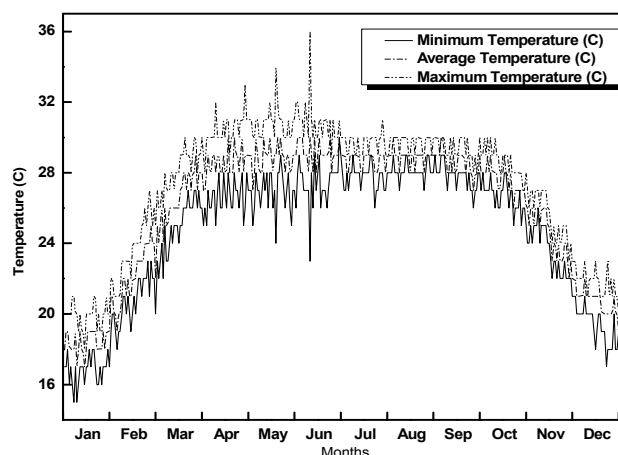


Figure 4. Average, maximum and minimum temperature throughout the year

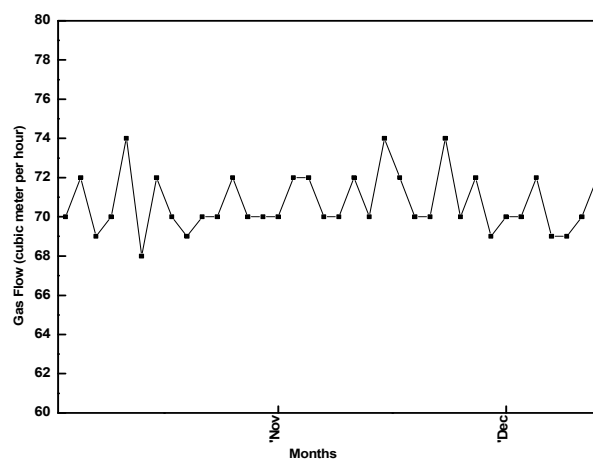


Figure 5. Gas flow over the year

Figure 5 shows that despite the temperature variations, as the temperature is controlled the biogas flow remains almost constant. The voltage remains constant at 400V over the year, but current varies with variation of the load as per Figure 6.

The frequency remains constant 50Hz over the year and rotational speed remain within 1% of the rated value over the year as shown in the Figure 7.

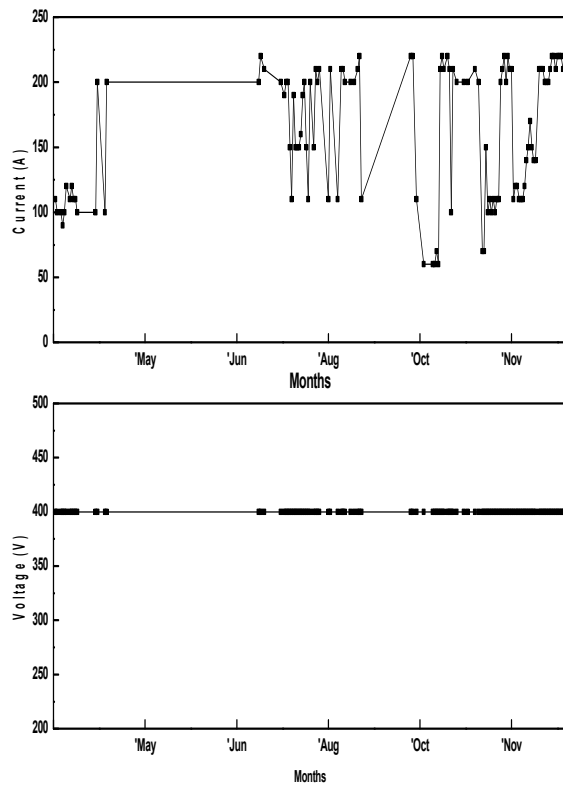


Figure 6. Voltage and current of the biogas plant with imported digester

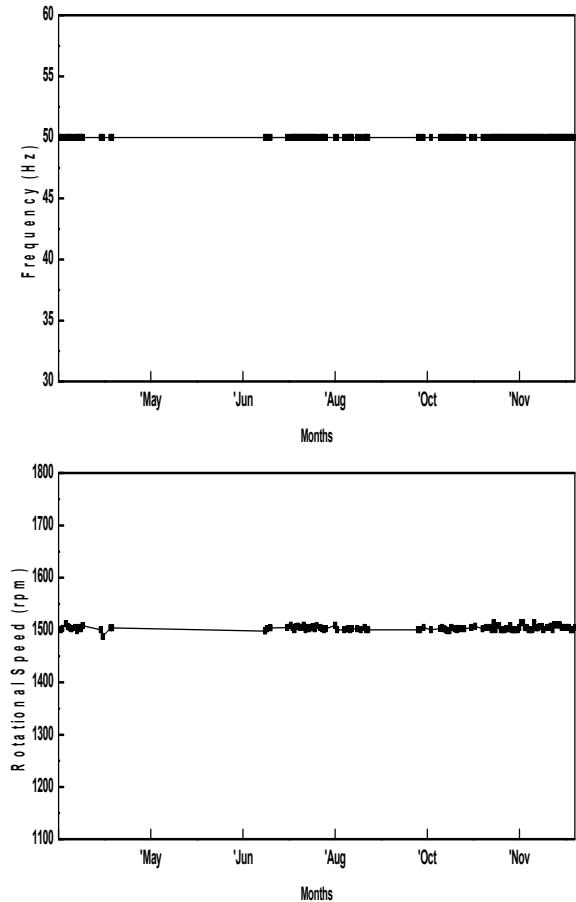


Figure 7. Frequency and rotational speed over the year for imported digester

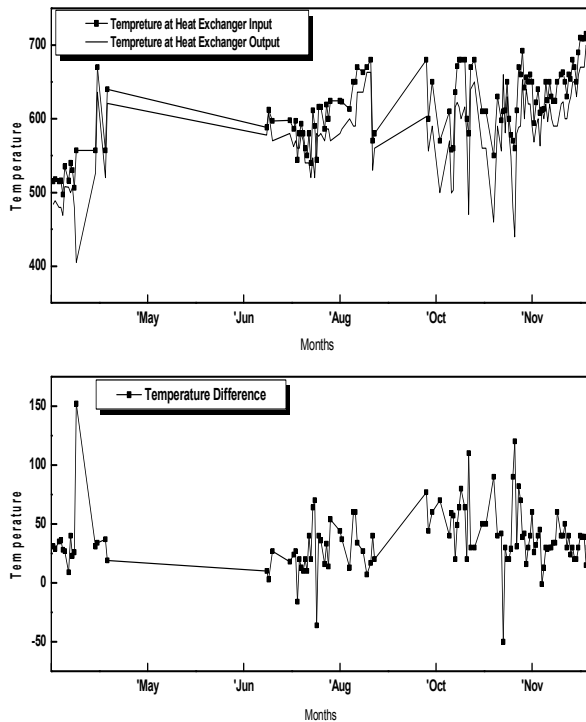


Figure 8. Temperature of exhaust at heat exchanger input and output and temperature difference

It shows (Figure 8) that during the cooler part of the year more heat required for maintain the temperature of digester hence the temperature difference is higher, but during the hotter part of the year the temperature difference is lesser as less heat is required for maintaining the temperature of the digester.

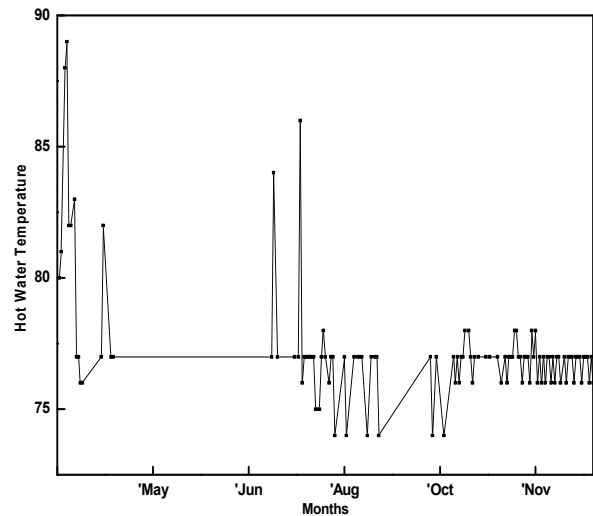
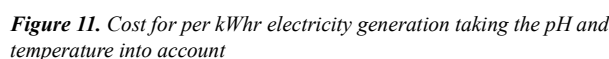


Figure 9. Hot water temperature over the year



The calculation shows that the overall biogas generation reduced by 12%. For extreme cold year the generation can be reduced by up to 20%. As the biogas yield decreases by 12% to 20% the generation cost increases. We shall use 12% reduction of biogas yield to calculate the generation cost of per kWhr electricity. Figure 11 below shows the normalized cost for per unit electricity generation.



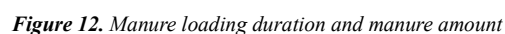
Periodic loading and unloading and unloading are very important for maximizing the biogas production. The periodic agitation of digester and mixing tank increases biogas production. Motors and pumps are used for imported digester for loading and unloading of manure. For agitation, pumps and motors are used. At PPL manure is loaded everyday at 8 am. Before loading, unloading is also done. Everyday 20 ton manure is pumped into the mixer, after mixing for 30 minutes the manure is pumped into digester for 2 hours (Figure 12 and Figure 13).

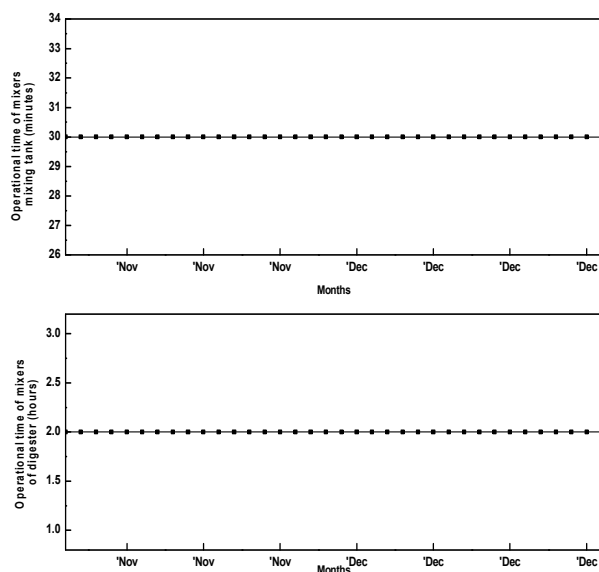
- 1) Case 1: Imported digester with all types of controlling schemes

- 2) Case 2: Local digester with no controlling schemes.

1) The plants which run for 14 hours can run for 24 hours now.

- 2) More biogas means less generation cost for per kwh.
- 3) Uninterrupted power supply for 24 hours which cannot be provided by even the national grid.
- 4) More power from biogas means less from diesel or other sources which reduces green house gas emission.





**Figure 13.** Operational time of mixers mixing tank (minutes) and Operational time of mixers of digester (hours)

But for generating more gas we need to deploy the controlling schemes which will,

- 1) Incur more cost for equipments and control module.
- 2) Will reduce operational cost as less operator will be required
- 3) Will reduce the size of the digesters as digestion with temperature control reduces the Hydraulic Retention Time (HRT) from 40 days to 20 days.

The cost of per kWhr electricity generation will be reduced for additional gas generation. Taking additional gas generation and additional investment required into account

the figure (Figure 14) below shows the comparison between two cases mentioned above.

So if additional control systems are deployed in locally made digesters then 38% money is saved. The digester with less 20m<sup>3</sup> sizes doesn't have any advantage of using control system as most of the energy is lost in the control system.

## 4. Conclusion

This research work represents the impact of different factors on production of biogas in different biogas plants of Bangladesh. The operation of different size of biogas plants throughout the country starting from 6.4 m<sup>3</sup> to 4000 m<sup>3</sup> have been analyzed in this paper. The impacts of temperature, pH, agitation periodic loading and unloading [17] on biogas yield are analyzed based on the collected data from survey, internet and other sources.

It has been found that most of the biogas plants don't have the schemes for controlling the temperature, pH, agitation, loading and unloading apart from few of the biogas plants which are imported. These imported biogas plants are well equipped to control temperature, pH, agitation, loading and unloading etc. Hence they produce up to 75% more biogas than the locally produced biogas plant. But for locally produced biogas plants additional controlling schemes can be provided making an additional investment. Although providing controlling schemes incurs additional costs but the increment in gas production suppresses the costs and the capital cost for per unit of electricity generation decreases by up to 38%.

**Table 1.** Detail of biogas plants studied

S/N	Daily Gas Production (m <sup>3</sup> )	Total Size (kW)	Name	Digester Type	Address	Mixing Tank	Digesters	Holding Tanks	Hot Water Tanks
1	6.4	2.4	Home Plant	Local	Rangunia, Chittagong	0	1	0	0
2	15	2	Jahangir Poultry	Local	Laxmipur	0	1	0	0
3	15	2	Green	Local	Solamasi, Keraniganj	0	1	0	0
4	20	2.5	Mohammadia Poultry	Local	Chowpally, Laxmipur	0	1	0	0
5	40	5	Ramu	Local	Cox's Bazar	0	1	0	0
6	40	6	Vision Poultry	Local	Sonagazi, Feni	0	1	0	0
7	70	8	Companigong Agro-Industries Ltd.	Local	Companiganj, Comilla	0	1	0	0
8	90	10	Bhuiyan Poultry	Local	Comilla	0	1	0	0
9	90	10	RMR Poultry and Hatchery Limited	Local	Laxminathpur, Rajapur, Pabna	0	1	0	0
10	90	10	Nazim Poultry	Local	Mauna, Gazipur	0	1	0	0
11	200	24	Electro Agro	Local	Gojaria, Shibchar, Madaripur	0	1	0	0
12	200	24	Fortuna	Local	Targas, Gazipur	0	1	0	0
13	300	34	Vulua Royal Chicks	Local	Sonapur, Noakhali	0	1	0	0
14	400	50	Rashid Krishi Khamar	Local	Trishal, Mymensingh	0	1	0	0
15	500	60	Paragon Poultry Ltd. (PPL)	Local	Sylhet	0	1	0	0
16	1000	100	Paragon Poultry Ltd. (PPL)	Local	Chandaner Hat, Gangachara, Rangpur	1	4	1	0
17	1200	122	Paragon Poultry Ltd. (PPL)	Imported	Chamiadi, Valuka, Mymensingh	2	1	1	1
18	4000	264	Paragon Poultry Ltd. (PPL)	Imported	Baniarchala, Bhavanipur, Gazipur	1	2	1	1

*Table 2. Amount of biogas yield from local and imported digesters*

Case No.	Manure Amount (t/day)	Total Solid (%)	Total Solid	Electricity Yield (kWhr/day)	Equivalent biogas (m <sup>3</sup> /day)	Biogas yield (m <sup>3</sup> /kg)
1	20	0.3	6000	6300	4018	0.7
2	0.08	0.2	16	10	6	0.40

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