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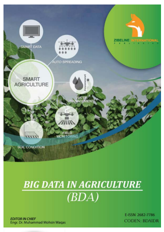

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RESEARCH ARTICLE

DEVELOPMENT AND TESTING OF SELF SUSTAINABLE BIO-REACTOR FOR BIOGAS PRODUCTION

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ABSTRACT

The increasing demand of energy and its production cost from the fossils fuels is directing to develops the renewable resources of the energy for the sustainable environment for the future generation. To cope the energy crises in the agriculture-based countries the scientific community was focusing on exploring new low cost self-sustainable biogas production reactor design. In this approach, biogas reactor was designed where solar energy as an input energy source for heating the feedstock in bioreactor was used. Optimization of biogas production at different temperatures were analyzed. A six liters double jacket reactor was developed in which hot water circulated. Hot water moved from solar collector to other side. The purpose of hot water circulation was to maintain inner tank (slurry tank) hotter every time. It's required temperature about 35^{o}C-45^{o}C for mesophilic conditions. Bio-gas production was tested at different temperature ranges. Production of biogas was tested at 10% total solids and 90% liquid. The findings show that higher temperature favored more yield. This study also focused on zero waste bio-reactor that could be used for further field application. Development of self-sustainable bio-reactor that has natural energy source (sunlight) and portable bio-reactor that could be moved to any place.

KEYWORDS

Self-Sustainable, Mesophilic, Bio-Reactor, Feedstock, Optimization.

1. INTRODUCTION

Fossil fuel consumption is increasing along with improvements in quality of life. Industrialization is increasing in developing countries, with increase of world population overall. It has been recognized that excessive consumption of fossil fuel leads to significant impact but also decline the fossil fuel reserves worldwide (Panwar et al., 2011). There is a lot of pressure in many areas of world to determine how animal waste can be handled for environmental sustainability. Animal waste disposal method causes serious effect on environment and health problems like air borne ammonia, green-house gases, and pathogen contamination. So there is dire need for appropriate disposal of livestock waste (Harikishan and Sung, 2003).

So, there is dreadful need to shift conventional heating system to an environmental friendly renewable system. It requires the design of an environmentally friendly biogas plant. Anaerobic digestion is implementation of waste to energy technologies. It has broad usage in treatment of different organic materials i.e. municipal solid waste, animal waste manure, sewage sludge and food waste (Li et al., 2009). A bio-reactor provides a controllable environment which is suitable for biological, bio-chemical and bio-mechanical requirements to manufacture engineering by-product. Bioreactor aims to create a desired biological product (Singh et al., 2014). Biogas optimal function is the provision of controlled environment by achieving optimal growth (Najafpour, 2007). There are principally three types of bioreactors involved: continuous, batch and fed-batch. Depending on the feeding strategy, culture and the medium use in the bioreactor. Traditional continuously stirred tank reactors (CSTR) and batch stirred tank reactors (STR) have existed for centuries. These are widely adopted in the bio-processing and chemical industry for production of biogas due to their simplicity. Other bioreactors may also be utilized, which have operational attributes and special design that are photo-bioreactors, mist bioreactor, rotary drum reactors, membrane bioreactor, packed bed bioreactors, air lift bioreactors, bubble column bio-reactors etc. These have been manufactured to provide specific processes (Fazenda et al., 2008).

Temperature has significant impact to enhance the biogas production. Mesophilic anaerobic process with temperature ranges from 35°C to 42°C has less production of methane as compared to thermophilic anaerobic (45°C-60°C) which result in high production. Furthermore, thermophilic conditions are more penetrating than mesophilic conditions (Mata-Alvarez et al., 2000). To deal with the above-mentioned issues, there is need to develop a new technology that not only be dependent of the cow dungs it also utilized the crop residues/diversified into the digesters (Weiland, 2010). In this study, the quantification of biogas production by self-sustainable solar powered bio reactor using cow dung is presented.

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2. MATERIALS AND METHODS

2.1 Designing of Bio-Reactor

The requirement of solar energy was calculated and designing was done accordinly, to supply solar energy for the operation of water pump and water flow requirements etc. The double jacket steel bio-reactor (6L) was made with water circulation coils, injection port, sampling port and temperature sensor port. Reactor holding stand was used as supporting frame. Reactor has agitating system, sampling port, collector coils and thermocouple. Furthermore, these parts attached with pump to circulate the water. Portable bio-reactor was designed. This designed bio gas plant has zero waste bio-reactor as slurry could be further used. Slurry can be pallarized with the help of palletizer or further used for composting. It was self-sustainable bio-rector that has no external energy source.

2.2 Different Plant Parts

Plant parts consists of following below components:
Digester inner tank, digester outer tank, gas analyzer, storage tank, sampling port, gas collection chamber/cylinder, inlet port, water collector coils (heat sensor), slurry outlet, water pump, temperature controller are used for designing of bio-reactor.

Figure 1: Showing portable biogas reactor

In figure 01 showed that, double jacket reactor in which two tanks were fitted. It had reservoirs capacity for water flow and a solar supply bio-reactor. Developed solar collector in which circulating coils made the water hot inside the coils. Storage tank was having capacity of 9 liters to store hot water. Solar pump was used to maintain water flow, its head was 1 ms^{-1}. This pump was operated at 40 watts solar (P.V) panel.

2.3 Experimental Setup

After development of biogas reactor, bio-gas production was tested at mesophilic temperature ranges. Cumulative biogas yield was tested at 10% total solids and 90% liquid. Feeding material was prepared by mixture of cow dung to water. The feeding material mixed well and fed to the fermented inner tank of double jacket reactor. Fresh animal manure was collected from dairy farm University-of-Agriculture, Faisalabad. Furthermore, this mixture was injected to the fermentation tank. The required reactor was fabricated locally. Heated water was injected to double jacket steel reactor with water circulating coils and reactor holding stand. Quantification of bio-gas production was tested at temperature ranges, mesospheric temperature (35°C-45°C).

2.4 Data Collection

Following parameters was tested i.e. Total Solids (TS), pH and Electrical Conductivity (EC). Their results were analyzed.

2.4.1 Total Solids (TS)

TS were the combination of total suspended solids and total dissolved solids.

2.4.2 Total Dissolved Solids (TDS)

Total dissolved solids were the aggregate of all organic and in-organic substances present in a liquid in ionized, molecular and suspended state. TDS were measured by TDS meter (Nawaz et al., 2020).

2.4.3 Temperature and pH

Digital temperature controller has a sensor which used to measure temperature, sensor was dipped into slurry tank. Slurry was stirred periodically by stirrer. Manual stirrer was attached into reactor. Complete mixing increased biogas production and pH was measured by using pH meter.

2.5 Anaerobic Digestion of Organic Matter

Anaerobic digestion followed by bio conversion sludge into slurry. It's a natural process which occurred biologically. It is biological process, breakdown the organic matter into simpler compounds such as carbon dioxide (CO_2) and methane (CH_4) and smaller amount of ammonia (NH_3), Sulphate (H_2S) and manure (slurry). Anaerobic digestion took place in basic four steps, hydrolysis, acidification, aceto-genesis and mito-genesis. Enzymes are active for degradation process. Diverse range of enzymes required a unique range of metals like nickel, cobalt, iron and zinc. These are essential cofactors.

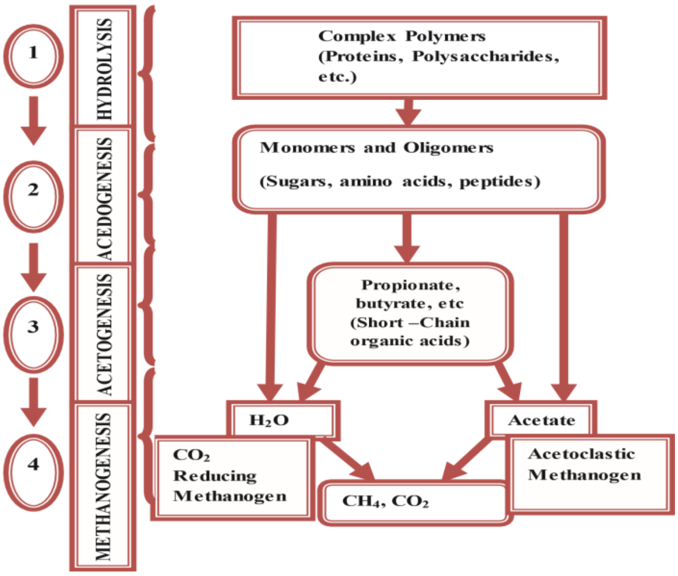

Figure 2: Four basic steps involved in biogas production

2.5.1 Hydrolysis

It is the main step of anaerobic digestion. It was an un-usual polymer separated from biomass. During hydrolysis polymers as fats, carbohydrates and proteins were separated to form smaller sugars molecules, fatty acids and amino acids. These molecules were still large enough to be separated again by acidogenesis process, which was useful for methane production.

2.5.2 Acidogenesis

In 2nd phase, amino acids, fatty acids and acidogenesis were fermented to short chain organic volatile fatty acids. This was largely due presence of propionic acids, lactic, valeric and propionic acids by fermentative bacteria.

2.5.3 Methanogenesis

It was final process of anaerobic digestion, where methane was produced. In this process carbon di-oxide, methane and acetic acid needed. Methane (CH_4) and (CO_2) were main products of this process.

2.6 Water Displacement Method

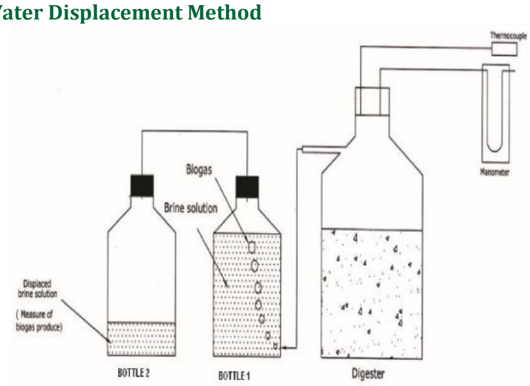

Figure 3: Schematic Diagram of the Water-Displacement-Method

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Water displacement method used for biogas collection. Biogas from bio-digester was allowed to enter in to 2nd chamber (Bottle 1), which contained brine solution (acidified). Biogas was insoluble in brine solution. A pressure built was supply a powerful force for displacement of brine solution in the (bottle 2) was calculated. Finally, displaced solution was calculated to represent the amount of biogas produced.

3. RESULTS AND DISCUSSION

3.1 Variation in Operational Parameter

The performance of bio-gas plant was controlled by evaluating and monitoring parameters such as loading rate, pH, and temperature. Any change in the parameters was affected the production of biogas adversely. So, the parameters should be within desired ranges for better efficiency of biogas plant.

Table 1: Different parametric characteristics of fresh slurry

Parameters	Volume (ml)	Total Dissolved Solids (TDS) (ppm)	pH	Temperature (°C)	Electrical Conductivity (EC) (μS)
Values	40	1006	6.60	25.4	2188

3.2 Cumulative Biogas Yield

In table 2 showed the cumulative biogas yield in hours for all three trial experiments. During 1st trail, in beginning there was no biogas produced because the digestion in slurry tank was not occurred. In next 24 hours, there was abrupt increase in biogas with time. However, after that biogas yield reached to its maximum digestion then it remains same onwards till 360 hours.

In 2nd trail, there was abrupt increase in cumulative biogas production after 24 hours and at 180 hours it showed maximum cumulative biogas yield. After 288 hours, it remained almost constant or little fluctuation in the yield of biogas production.

Table 2: Cumulative biogas yield for different trial experiments

Time (Hours)	Cumulative Biogas Yield (mL)		
	Trial-I	**Trial-II**	**Trial-III**
0	0	0	0
24	305	200	197
48	395	395	443
72	750	769	758
96	1150	1045	1087
120	1495	1495	1495
144	1950	2108	2067
168	2404	2395	2404
192	2435	2435	2750
216	2455	2490	2786
240	2515	2545	2789
264	2600	2595	2797
288	2602	2591	2828
312	2605	2603	2835
336	2604	2610	2843
360	2606	2612	2856

In 3rd trail there was gradual increase in cumulative biogas yield after 72 hours. It was due to higher temperature and high digestion inside the slurry tank. It has reached 2856 ml in 360 hours maximum. After 192 hours, the cumulative production showed little fluctuations.

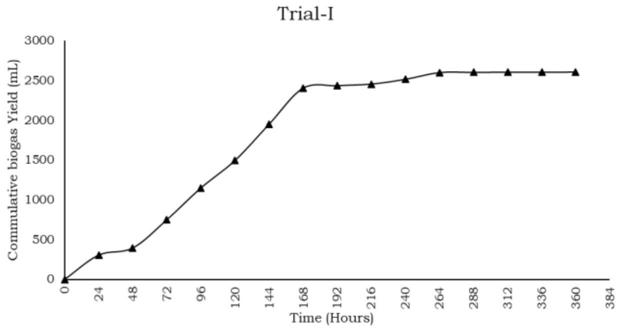

Figure 4: Cumulative biogas Yield against time

In figure 04, graphs showed that there was abrupt increase in cumulative biogas production after 24 hours in first trail. Moreover, in 180 hours, it showed maximum cumulative biogas yield. After 288 hours, it remained almost constant or little fluctuation in cumulative biogas yield (ml).

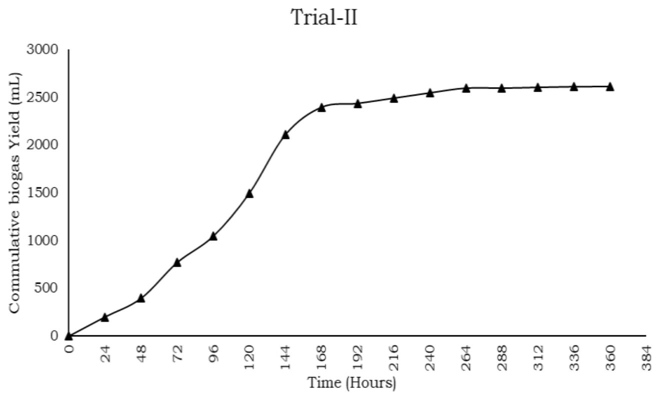

Figure 5: Cumulative biogas yield against time

In figure 5 graph of the second trial showed that there was abrupt increase in cumulative biogas production after 24 hours. At 168 hours it showed maximum cumulative biogas yield. After 288 hours, it remained almost constant or little fluctuation in biogas productions (yield).

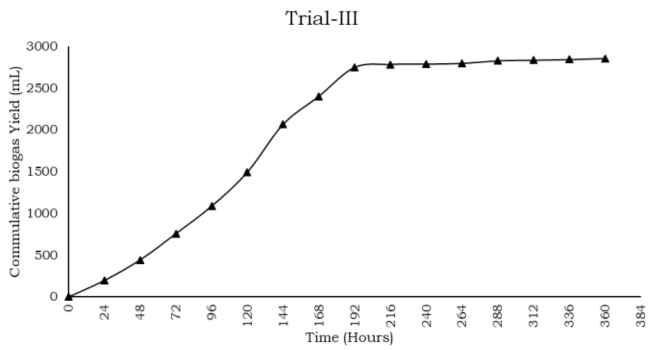

Figure 6: Cumulative biogas yield against time

In figure 6, the graph showed that there was slow yield in first 3-4 days then the production of biogas increased abruptly due to high slurry temperature. These graphs (figure 4-6) revealed that the variation in production of biogas, as high temperature inside the fermentation reactor and slurry temperature also a suitable for the microbes. Due to high temperature, there was more production of biogas as compare to starting time (hours) because temperature is less at start of reaction. Furthermore, at the end of experiment days (hours), there was low volatile solid content and also water content was decreased due to batch type reactor. Manual stirring was also a drawback of lower yield.

3.3 Practical Application

Using cow dung as a feeding material was an excellent opportunity to reduce waste which could cause hazard or foul smell to the surrounding areas. Using solar based collector enhanced the use of renewable energy sources. It was a self-sustainable bioreactor which could be moved any place. Testing of bioreactor was done by performing different experimental analysis. Further, slurry was used to make pellets with the help of pelletizer.

4. CONCLUSION

This study concluded the development of self-sustainable solar based biogas reactor. Double jacket reactor was made with stainless steel. Each part was developed through mechanical working in highly supervised workshop. Best angle for absorption of maximum sunlight radiation to solar collector. Performance of solar based biogas reactor was tested for 0 hours to 360 hours in three trails. Cow dung was used as feeding material because it has maximum cumulative biogas yield. Results revealed that mesophilic temperature range was most appropriate to yield biogas production. Thermophilic temperature ranges were not suitable for biogas production. It can give yield more at certain temperature range but it eventually kill micro-organism that are required for optimum quantity of gas production. In addition, thermophilic conditions suitable in cold climate region or winter. Hence in our region where purpose of study to use solar based biogas plant. Mesophilic (35 ^{o}C-45 ^{o}C) temperature ranges were suitable to maintain temperature.

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