Design and construction of automatic laboratory reactor biogas and potential evaluation of biogas of biomass

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Abstract: Increasing energy demands in different sectors of the world societies has faced a major challenge. Decrease of fuels such as oil, coal and natural gas as non-renewable fuels and fuel price increases highlights the importance and need of replacing the current energy systems. One of these choices is the use of energy from biomass sources. Biogas as one of the energy sources is obtained from decomposition and fermentation of agricultural residues, animal and human wastes and industrial waste to produce methane gas. Some of these materials come out from biogas machine as sludge compost which their fertilizer quality is good. Biogas can be used as well as an energy carrier to replace fossil fuels. The objective of this study was to design and construction of automated laboratory reactor biogas and to produce biogas from different raw materials. Programmable and automatic control reactor has been designed and equipped with 50-liter-scale digester, mixing and heating systems, digital pH metre. Structural type of the digester was batch type. Devices that measure the volume of gas produced from an electronic circuit, 3 solenoid valves, transfer tubes, glass containers and stored in distilled water into the measuring cylinder gas (hypocrite), also designed and built. The reactor produced biogas biomass potential can be determined from the rate of biogas production and thus meet the energy needs of the region.

[Salamollah Mohammadi-Aylar, Yousef Abbaspour-Gilandeh and Morteza Almasi. **Design and construction of automatic laboratory reactor biogas and potential evaluation of biogas of biomass.** *Life Sci J* 2013;10(1s):38-42] (ISSN:1097-8135). http://www.lifesciencesite.com. 6
Keywords: Biogas, reactor design, biomass.

1- Introduction

Biogas is produced through a process called anaerobic digestion by which organic matter is decomposed by oxygen without microbiological activity. This phenomenon is produced naturally in swamps, animal and human digestive system and wastewater is also produced naturally and sometimes is incomplete (Anonymous, 1387). Livestock wastes have significantly impacted energy and can be used to produce biogas. In our country, there are 72 million of livestock that their waste can be utilized for producing about 4 million cubic meters of methane gas which equal to the energy of 25,500 barrels of petroleum. China and India have huge plans to produce biogas. China is producing yearly more than 7 million cubic meters of biogas. This biogas is supplying the energy needs of more than 50 million rural peoples (Adl, 1999).

According to the conducted studies in Islamic Republic of Iran, there is the potential of production of biogas from livestock waste equivalent to 25,500 barrels of petroleum energy yearly (sadaqat Hosseini, 2003). Wastes from a 600 kg bull could produce daily about 1.5 cubic meters of biogas; manures of a 90 kg animal could produce daily about 0.2 cubic meters of biogas; and excreta of a 2kg chicken could get about 0.01 cubic meters of biogas (Almasi, 2008). Sweden is one of the best users of biogas in the transport industry as 4,500 vehicles of bus fleet are using about 45% of the needed fuel from the biogas. According to this report, the costs of biogas production are more profitable than gasoline production in Sweden. Because, the cost of producing one cubic meter of biogas, which includes the cost of production, modification and compression is about 3.5-4.5 SEK and this is only 70% of the current cost of gasoline production in Sweden (Easterly, Faij, & Flavin, 2007). Biomass refers to the dead or alive biological materials (plants and animals), which are not yet fully decomposed or fermented. Swamp gas or biogas is produced from fermenting biomass. In general, crop plantation is possible in two-third of the Earth's land. The energy of these plant materials can be used in energy production, but currently only 15 to 20 percent of the land is cultivated (Sattari Sarbanqly, 1999).

According to Safa (1997) study, the average of biogas production increased about 42% when paddle agitator was used. The reduction percentage of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) in this digester reported 90.2 and 89.2, respectively, and the average percentage of the sludge pH were reported 7.5 (Safa, 1997).

Hosseiniyeh (2006) reported that in wastewater using anaerobic methods, the rate of methane production (depending on factors such as the treatment process, conditions created during purification, the amount of organic matter, temperature, pH, etc.) in the first six months of year, is about 1275-850 cubic meters per day and the second half is about 1570-2125- cubic meters per day (Hosseiniyeh, 2006).

2- Materials and Methods

2-1-Design and construction of the reactor system

In this research, structural type of digester was chosen as batch type. The type of biogas producing device is the Chinese type. Three polyethylene digesters of 50 liters capacity were used in the system. Two holes were created on digesters for incoming and outgoing materials. Then two small vents in the lid of the digester gas output were created to measure pH online and another hole was embedded under the tank for the shaft of mixer motor.

Heating system was equipped with a 500 watt anti acid glassy heating elements and a thermostat to control the temperature. Selected elements have ability to maintain the ambient temperature between 30-70 °C.

The ammeter is connected to elements to determine the wattage. To smooth out the solution an electric mixer motor was used to prevent bacterial colonies in different parts for producing the same gas quantities. A DC motor was used to observe safety precautions to prevent injury, which was controlled and programmed between 30-120 rpm. Also ammeters were used to determine the wattage of each motor which can be individually identified.

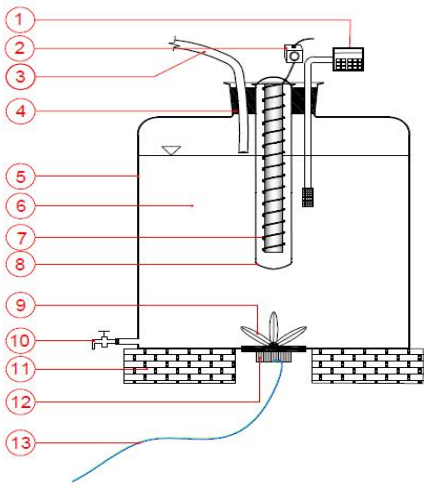

Figure 1: Schematic figure of automatic biogas reactor system

1-pH meter 2-Thermostat 3-Gas outlet pipe 4-Digester entry 5-Digester tank 6-Solution digestion 7-Heating elements 8-Glassy element 9-Blade mixer 10-discharge valve 11-Basic digester 12-Motor Agitator 13-Wire of electricity agitator

2-2- Measurement unit of the volume of produced gas

A system was designed to measure the volume of output gas. The main problem was that the conventional transducers could not be used for measuring outlet gas volume due to the very low gas pressure. Therefore, at beginning, it must be determined the total amount of gas in a chamber volume and when it was determined by measuring system, the valve would be opened and it was out of gas.

Gas volume measuring device is composed of an electronic circuit, 3 solenoid valves, transfer pipes, glass containers for storing the distilled water and a measuring gas cylinder. Distilled water is used because the minerals in ordinary water buildup sediments on sensors and prevents the sensor is working correctly. Of course, there is a need for an amount of salt for sensor operation which is performed by adding 30 mg of salt per liter of water manually.

Accordingly, the volume of graduated cylinder was considered about 150 ml. When the amount of gas is collected in a graduated cylinder, solenoid valve at the top of graduated cylinder opens and the volume of the produced gas, date and time is stored in the memory of the storage device.

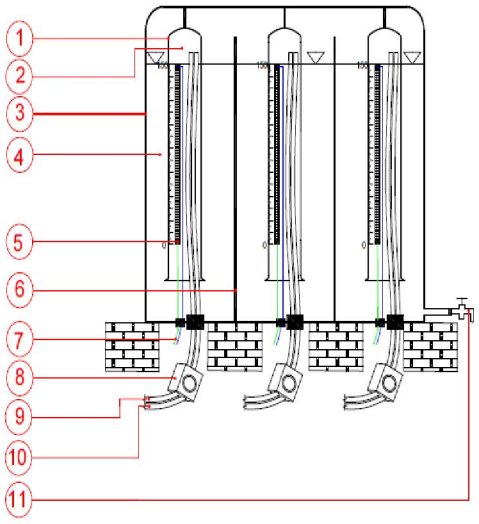

Figure 2- Schematic diagram of a device measures the volume of the produced gas

1-Glassy graduated cylinder 2-Glassy graduated cylinder empty space 3-Glassy repository 4-Distilled water 5-Sensors measure the volume of the produced gas 6-Base of the glassy repository separator 7-Electrical wire of sensor 8-The solenoid valve 9-Gas input hoses from the digester 10-Gas outlet hoses from the reservoir after measure the glass 11-discharge valve

2-3 Micro controller circuit of reactor agenda

1- The circuit is on and all of quantities on a display board are 1.
2- The water level is initially on UP.
3- Solenoid valve is close and the gas is entering graduated cylinder.
4- Every 4 used contacts, 2 contacts in the up level and 2 contacts in the down level, are inside water.
5- Over the time and with continuous entering of the gas, the water level is going down, but solenoid is still close. The display board is showing 0 for up level and 1 for down level. These numbers indicate that when the base of the sensor is connected, the number of 1 is shown on the board and when the connection is lost 0 appears on board.
6- Just when the water level crossed the down level, the connection of two contacts in down level discontinued, circuit operates and the solenoid valve opens to be out of gas in the graduated cylinder.
7- When a small amount of gas was removed, the water surface comes up in the glassy graduated cylinder and reaches to down level. Two contacts in down level are connected, but this connection should not affect the level or change in the circuit to evacuate gas from the top of glassy graduated cylinder.
8- The water surface comes up inside graduated cylinder by discharging the gas.
9. The water surface comes up to up level and two contacts in up level are connected. Now circuit operates and solenoid valve in the output closes graduated cylinder while one unit is added to the screen (Again, at this moment every 4 contacts are inside the water).
10- Steps 2 onwards are repeated.

The designed demo for LCD when the circuit is ON is as follows:

1-Press Start Button
2-Water=1 No Water=0
3-Down=Low sensor UP=High sensor
4-D=Down UP=UP

2-4- Loading the Device

Materials brought to the laboratory from the nearest livestock which was located around the city of Ardabil, Iran.

2-4-1- Nutrition

Waste and water were mixed with a 1:1 ratio. Because the fresh manure contains about 20% of solid material and 80% of moisture, this ratio will get the percentage of total solids of sludge to 7-9. Several tests have been determined that 7-9% of solids in the sludge will create the most favorable conditions in gas production. It should be noted that entry of foreign materials such as dirt, gravel, sand, sawdust, soap and detergent should be prevented. A separate tank was used for sample pretreatment for mixing the material with water and then the sample was entered to the digester.

2-4-2- loading amount

Due to the size of the tank (50 liters), 70-80 percent of its volume can be filled with material.

2-4-3- Agitator

Agitating was done with 3 different rotational speed for 45 minutes per day. In other words, agitating was performed with three rotational speeds of 30, 60 and 90 rpm, 3 times per day and 15 minutes in each stage. It is worth mentioning Agitator quantity and turnaround time is changed into the desired quantities. All cases are stored in RAM.

Table 1: Agitator speed

Digester No.	Agitator speed
1 2 3	Slow rpm 30 Medium rpm 60 Spicy rpm 90

Table 2: Amount of ampere consumption for any motor

Engine No.	Ampere
1 2 3	1.2 1.5-1.8 2.4

Using that ammeter is installed on the device; it is possible to calculate the amount of ampere consumption for each engine.

2-5- Experiments

The main experiments were conducted with loading cow manure. Material freshly prepared, therefore, to get the exact amount of VS, material brought to the laboratory and precise tests were done there. Vs (total solid), Ts (volatile solid), W(weight).

W_3 4/73gr W_2 17/67gr W_1 100gr

TS 17/67% VS 73/23%

By adding water the needed concentration were achieved. After homogenization of material, digesters were filled with 30 liters material. Inside each digester, a digital pH meter measured pH levels which the average was reached to about 6.9. After spending a few days, a reasonable amount of methane gas produced. The gases collected in separate tubes and then were transferred to the laboratory for analysis.

3- Results and Discussion

According to the Figure 3, it can be concluded that in the early days of the start of the the experiment, There was very high rate of biogas production. So that until the day of 12, which has produced about 51300 ml of biogas, this amount is equivalent to 85/7% of total biogas production.

Gas production velocity in the tank as Before the tank was very high early From day 12 onwards is greatly slowed down. Calculated cumulative the data suggest that 63150 ml amount of biogas produced in the first 12 days This amount is equivalent to 82% of total biogas production in this period. The calculated cumulative data in the third tank It comes the 55800 ml of 83/9% of total biogas production of the first 12 days of starting the test.

X = time Y = volume in ml of gas produced based

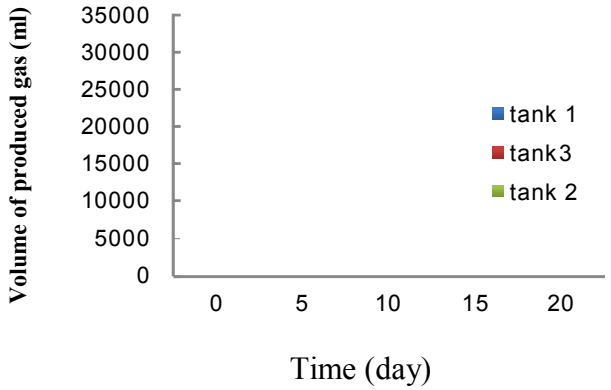

Figure 3: Gas production

Table 3: Volume of gas production

Digester No.	The amount of produced gas per liter
1	59.850
2	76.950
3	66.450
Total	203.250

To comprise the treatment in terms of quality of produced biogas, samples were stored in separate tubes for analysis of biogas production and were transferred to the laboratory. The following analysis of variance of nitrogen could be seen in two batches separately.

Table 4: Analysis of Variances of Nitrogen

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	51.585[a]	1	51.585	2.933	162.
Intercept	924.841	1	924.841	52.577	002.
Treatment	51.585	1	51.585	2.933	162.
Error	70.360	4	17.590		
Total	1046.786	6			
Total	121.945	5			

a. R Squared= .423 (Adjusted R Squared= .279)

According to the analysis, agitation of the material has no significant influence on the rate of the nitrogen production.

Table 5: Analysis of Variances of methane

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	[a]16.729	1	16.729	0.708	447.
Intercept	15910.163	1	15910.163	673.491	000.
Treatment	16.729	1	16.729	0.708	447.
Error	94.494	4	23.623		
Total	16021.385	6			
Total	111.222	5			

a. R Squared= .150 (Adjusted R Squared= -.062)

According to the table 5, the rate of agitation is not significant on the production of methane..

Table 6: Analysis of Variances of CO_2

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	[a]127.067	1	127.067	9.273	038.
Intercept	7814.957	1	7814.957	570.318	000.
Treatment	127.067	1	127.067	9.273	038.
Error	54.811	4	13.703		
Total	7996.835	6			
Total	181.878	5			

a. R Squared= .699 (Adjusted R Squared= -.623)

According to the table 6, analysis showed that the rate of agitation has no effect on carbon dioxide.

Table 7: Cumulative percent of biogas production

	Tank 1	Tank 2	Tank 3
Cow manuar (12 days)	%85	%82	%83

4- Conclusions

In this research, to achieve the objectives of the study, there was a need to design and construction of a biogas reactor. To determine the amount of biogas produced from different materials, the device was designed and constructed. The quality of the produced biogas was tested and analyzed in lab. More than 80% of the resulting biogas is produced in the first two weeks; therefore it can be concluded that in the first two weeks, anaerobic bacteria multiply and began to feed. After spending a few days, reduced concentration and food shortages are causing inactivation of bacteria. In this case, there is a sharp drop in biogas production. With considering economic perspective, it is clear that the last week has almost no benefit to preserve the digester and only increases production costs.

5- Acknowledgment

This paper resulted at project was conducted with financial support from Ardabil Branch, Islamic Azad University and I hereby thank the authorities of the University.

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