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Biogas Production from Agricultural Wastes in Laboratory Scale Biogas Plant

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ABSTRACT: This study was within the context of "The Production of Biogas from Agricultural and Animal Wastes and Utilization of Obtained Gases in Integrated Energy Conversion Technologies (BIOGAS)" project which was running under "Public Institution for Research and Development Project Support Program (1007)". Laboratory Scale Biogas Plant was manufactured under this project and this plant was placed in laboratory of Akdeniz University Agricultural Faculty Agricultural Machinery department. The study was carried out only in the production of biogas using waste plant material. Four different variations were used in this study. 25 days of data were evaluated for each variant. Vegetable wastes, which were taken from the main kitchen of Akdeniz University, were used as a material. The materials as used vegetable were carrot, cabbage, leek, lettuce, parsley, onion, potato and cucumber wastes. Experiments were accepted with two different dry matter content (9% - 12%), two different fermentation temperatures (35-45 ^{0}C) and two different retention times (30-40 days). As a result of this research, the highest biogas production was 1190,9 l/d in variant 3 which 12% dry material and 30 days retention time was used. The lowest biogas production was 1068,0 l/d in variant 2 which 9% dry material and 40 days retention time was used.
Key words: Laboratory scale biogas plant, agricultural wastes, biogas production

INTRODUCTION

The fossil resources which run out day to day cause gradually increasing demand for energy in the world. The use of fossil fuels, foreign dependence, import costs and environmental problems brings significant drawbacks. So, the importance of renewable energy sources are increasing every day and developed countries in this regard is to make large investments in R & D projects. In our country, biogas technology has been tried to apply within the research level and limited knowledge and technology. The first biogas studies in Turkey had been carried out in 1950's (Yaldız, 2000). Since several pilot scale plants built by Soil and Water Institute were not designed properly, thus plants did not work successfully. Biogas production took first place in the environment and renewable energy work because of the development of environmental awareness and use of local resources for energy production but development of this regard couldn't increase in Turkey. Also manpower, technology and the level of awareness are not needed to be. Biogas plants constitute an important stage of energy production and environmental protection due to environmentally sensitive. Waste mountains were occurred because of waste composed after agricultural production. The wastes composed after agricultural production and usage of agricultural products seems as an important problem. This problem is tried to be solved by steering the organic agricultural wastes composed as a result of intensive production to re-use in production. Also the management of agricultural wastes in distribution of scarce resources is an important factor in the economics (Yaldız et al., 2010).

The main purpose of this research is to determine of biogas production from different materials.

MATERIALS and METHOD

This study was constructed by considering the environmental, economical and technological benefits for using agricultural wastes. The tasks in this study includes: review biogas and energy production technologies, design and development of lab-scale integrated biogas plant by using agricultural wastes (Kaya et al., 2008). This laboratory scale biogas plant has 1,2m^3 gross volume but the net volume of fermentation is 1m^3 and it is vertically cylindrical. This mechanism was placed on a platform with wheels. This mechanism consists of a fermenter, water channel used for heating system, two mechanic mixers, material preparation tank and control board. Also there is trolley to carry out the output material. This laboratory-scale biogas plant is shown in Figure 1.

Charging and discharging pipe was mounted on fermenter. Charging pipe is connected to the sludge pump which is inside the material preparation tank. Discharging clearance made to takeout the fermented material from the system. This material is taken to the trolley. Fermenter is mixed with two different mixers to provide effective mixing during the experiments. One of this mixer is paddle mixer. It is mounted up and rotating with 30 min^{-1} and it has 0,75 kW power. Other one placed next to the fermenter and it is convertible rotating with 400 min^{-1}. It has 0,75 kW power. Rotation speed can be changed on the control panel.

Inside of the material preparation tank, material derived from fragmentation unit is diluted with water and mixed homogeneously. Material is loaded to the fermenter with mud pump. Operating time of that pump can be adjusted on the control panel. This unit is manufactured from 304 stainless steel material. The base of the tank has been inclined to reduce deposits. Mixer is placed perpendicularly to ensure homogeneous mixing of the material. Working volume of the reactor after filled with agricultural waste, discharged from reactor as a fermented material. This material is taken away from the system with trolley. Produced biogas is taken from the top of the fermenter than is sent to pressure stabilizer. Biogas which comes from water trap is taken into storage (type of balloon) with flexible pipe. Biogas is transferred to the flow meter for the examination of the amount of daily produced gas before analyser. The biogas from the balloon-type storage is transferred to gas analyzer for determination of the content. Temperature control, mixing and blending cycle time can be adjusted with PLC automation equipment in the system.

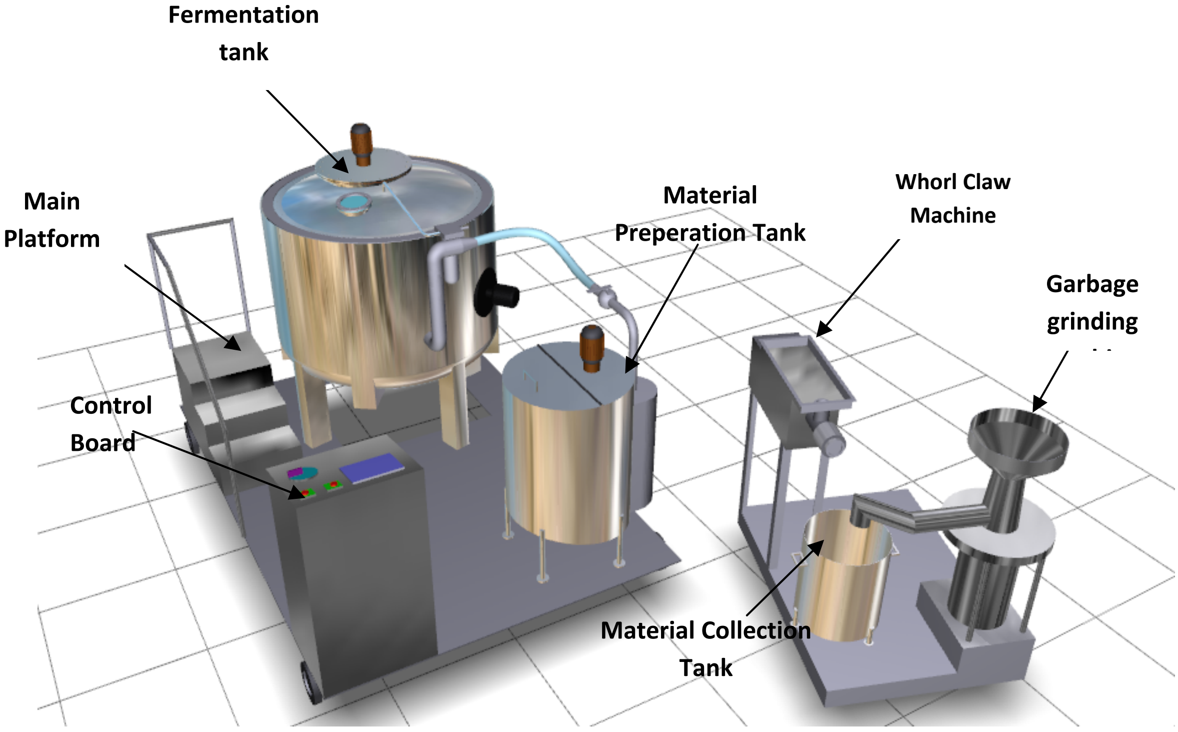

Figure 1. Schematic picture of the laboratory scale biogas plant

Table 1. Research plan

Material	Experimental Variant	Fermentation temperature (^0C)	Retention Time (Day)	Dry Matter (%)	Loading Rate (g.odm/l.d)
Agricultural Material	AM1	35	30	9	3,0
	AM2		40	9	2,25
	AM3		30	12	4,0
	AM4		40	12	3,0
	AM5	45	30	9	3,0
	AM6		40	9	2,25
	AM7		30	12	4,0
	AM8		40	12	3,0

odm= organic dry matter

All system can be controlled on the screen. Taking the data obtained in the experiment can be provided and stored. After the data became stable, experiments are continuing with the changing experimental parameters.

The study was carried out by using waste plant materials but fermenter was firstly loaded 1/3 cattle manure before starting process because of increasing methane bacteria population. Then, agricultural wastes which was accepted from experimental station was started to load. It is main reason that to continue with agricultural materials after starting cattle manure fermentation in biogas plants which works with agricultural wastes. The materials used as vegetable were carrot, cabbage, leek, lettuce, parsley, onion, potato and cucumber wastes. The rate of these wastes in the mixture were calculated as 17,8; 30,3; 24,4; 13,3; 2,2; 2,7; 5,9 and 3,4% respectively. Agricultural materials were bring to laboratory, but cannot be used because of their actual sizes. Therefore the pre-processing is required. For that pre-processing two different shredder was manufactured. This system was placed on other platform which is 110x150cm. One of these machine is screw shredding machine and the other one is garbage grinding machine.

Experiments were done with two different dry matter contents, fermentation temperatures and retention times. Dry matter content was 9% - 12% and retention time was 30-40 days and also fermentation temperatures was 35 and-45 ^0C. In this case four different trial variants were used (Table 1). 25 days of data were evaluated for each variant. This process has enclosed approximately 4 months. Rest of the period was used as to start fermentation and standby.

Data were taken at the same time regularly and loading processing was done. The material, in the material preparation tank, was mixed as a priority before doing the loading process. After this mixing process, the loading process was done as the mud-pump running pre-determined period of time. This process was realized by a button on the touch point screen of the PLC system. Mixing and pump operating time can be adjusted automatically according to demand. The amount of biogas, which was produced in generator, the content of biogas and the pH value of the material, dry matter and organic dry matter content were daily determined.

The produced biogas was passed through a pressure stabilizer as taking with a pipe at the top of the generator. The biogas, which was passed through pressure stabilizer, was transmitted by a tube to digital flow meter. The flow meter was reset at the same time every day, as reading the total amount of gas. A gas analyzer was used when determining the amount of methane of produced biogas. This device determines methane, carbon dioxide, oxygen and hydrogen sulfide gases. Measuring device sends the gas, through a pump and a tube connected with it to its sensors and determined values are shown digitally on the screen.

pH value of the fermentation material was measured by the digital pH meter, which had glass probe. Both the pH value of entering and exiting fermentation material was determined regularly.

Before the measurement is provided, the material was mixed perfectly to become homogeny condition. The pH value of material, which was prepared before the generator spilling process and was accursed immediately after spilling, was determined without any delay. The sampling probe which was stacked into the material was waited until the reading value fixed and then reading was done. The device has the specialty of automatically reporting of calibration demand to user. It was very important that taking accurate and liable values as doing calibration of the pH meter by buffers when attention came.

The three samples were taken every day from the material which was spilt into the generator. These samples were put in cylindrical porcelain krozes. The samples were put into drying cabinet, set 105^{o}C, after taking the tare of the krozes. The damp, in the samples, was disposed by waiting 24 hours. The amount of dry matter was calculated using the method of weight reduction as the result of measurements. This method which is used to determine the amount of dry matter and used to examine water and waste water is a standard method (APHA, 1995). The measurement process was done by a digital balance which has the specialty of 1% precision and automatic calibration.

The krozes, which were taken from drying oven, were put into the burning oven to determine organic dry matter content. They were burned at 550 ^{0}C at least 4 hours until to be the fix weight. As the result of burning, the organic materials were disappeared and only the inorganic materials, which content the sample, were remained in the containers. The calculation was done using the weight reduction method from the remaining ash. This method which is used to determine the amount of organic dry matter and used to examine water and waste water is a standard method (APHA, 1995)

RESULTS and CONCLUSIONS

Biogas production and methane rates are shown Table 2. The highest biogas production was 1190,9 l/d in AM3 which has 12% dry material and 30 days retention time and the lowest biogas production was 1068,0 l/d in AM2 which has 9% dry material and 40 days retention time. The fermentation process was not in stable at fermentation temperature of 45^{0}C, the pH value was decreased to 6 and biogas production is very fluctuating. So, there were lack of data to evaluate production. As a result, the fermentation temperature of 45^{0}C for this plant material composition is high and some biochemical analysis should be made to find out adverse fermentation parameters.

In biogas production, increase of the dry matter rate provides increase gas production if retention time constant. The same results were obtained with high rates of dry matter in many basic research. Decomposition of dry matter increases with increase of fermentation temperature (Weijan et al., 1994).

Increasing of loading organic dry matter is increased total gas production, but it decreased the rate of dry matter utilization. Specific biogas production of raw materials is shown Table 3.

Table 2. Biogas production under 35^{0}C fermentation temperature, different dry matter rate and different retention time

Experimental Variant	Biogas Production (l/d)	Standard Deviation (l/d)
AM1	1108,5	290,7
AM2	1068,0	154,4
AM3	1190,9	147,7
AM4	1171,7	234,5

Table 3. Specific biogas production of raw materials

Experimental Variant	Bv (l/g.odm.d)
AM1	0,32
AM2	0,30
AM3	0,34
AM4	0,33

Specific biogas production of fermenter is very important factor for the economically biogas plant manufacturing. In this study, biogas production in AM1 is less than AM3 and biogas production in AM2 is less than AM4. Retention time remains the same and increase the rate of dry matter has led to produce more gas per unit volume of fermenter. Fermenter specific biogas production during experimental duration is shown Table 4.

Table 4. Specific biogas production of fermenter

Experimental Variant	Specific biogas production of Fermenter (l/l.d)
AM1	1,10
AM2	1,06
AM3	1,19
AM4	1,17

Specific methane production of fermenter is defined as methane production per volume of fermenter per day. Specific methane production of fermenter calculation is considering biogas production and fermenter value. Specific methane production of fermenter is shown in Table 5.

Increase of the loaded organic dry matter leads to decrease specific methane production of raw matter when other fermentation conditions remain the same. The same results were determined in this study too. Specific methane production of raw matter during experimental durations is shown in Table 6. In plant materials, while the cellulose content is higher, the bacteria population is lower than cattle manure. So, the decomposition is more difficult during hydrolysis level of fermentation in plant materials. Thus, the biogas production without addition of micro elements is lower in pure plant material wastes. While the specific methane production was 0.21 l.g $odm^{-1}.d^{-1}$ at 30^0C for cattle manure (Yaldız, 1987), this value was reached its maximum as 0.18 l.g $odm^{-1}.d^{-1}$ in AM1.

Table 6. Specific methane production of raw matter

Experimental Variant	M odm (l/g odm.d)
AM1	0,18
AM2	0,18
AM3	0,14
AM4	0,15

pH value is increased to suitable level for production of biogas. The reason of that is produced acid transfer to the methane. Generally, pH value for biogas production should be 7 or over. pH value of material is shown in Table 7.

Table 7. pH value

Experimental Variant		pH Value
Raw Matter	%9 dm	3,97
	%12 dm	4,05
AM 1		7,73
AM 2		7,87
AM 3		7,84
AM 4		7,81

Content of the biogas (O_2, CO_2, CH_4, H_2S) is shown in Table 8.

Table 8. Biogas content

Experimental Variant	CH_4 %	CO_2 %	O_2 %	H_2S Ppm
AM 1	55,3	43,2	0,57	526
AM 2	50,3	47,3	1,0	452
AM 3	54,5	42,6	1,60	521
AM 4	47,4	50,1	1,20	448

CONCLUSIONS

As a conclusion of this research, the highest biogas production was 1190,9 l/d in AM3 which has 12% dry material and 30 days retention time and the lowest biogas production was 1068,0 l/d in AM2 which has 9% dry material and 40 days retention time. The pH value of raw material was measured as 3.97 at 9% dry material while it was 4.05 at 12% dry material. The pH values of the experiment variants were measured 7.73, 7.87, 7.84 and 7.81, respectively. CH_4, CO_2, O_2 and H_2S composition of the biogas was reached their highest values as 54,5% in AM3, 50,1% in AM4, 1,60% in AM3 and 526 ppm in AM1, respectively.

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