Providing Electricity Requirements by Biogas Production and Its Environmental Benefit in Sample Dairy Farms of Iran

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Abstract- This research evaluates and estimates biogas (methane) production potential from cattle manure through anaerobic digestion processes in some dairy cattle farms of Iran. The gas can be used to produce electricity, to heat water for farm use, or for other business ventures that use energy. By measuring the manure production in each dairy farm and the electricity use, the biogas production and consequently the electricity generating potential was assessed. Few previous researches and projects have been carried out on this subject. As the result of this study, there is the potential of 15190.3 m^3 day^{-1} biogas production which is equal to 7595.15 m^3 day-1 methane (CH_4) gas in the region for 47 dairy farms with 11862 head of cattle. This amount of biogas has the potential to generate electricity as 77428.3 kWh day^{-1}, which is more than the total electricity requirements of the target dairy farms. The CO_2 gas emission was also estimated due to the Methane value (0.04 tons/year). Based on the results and the environmental benefits of utilizing biogas, educating farmers through extension programs, making new policies for extending the idea of extracting biogas from cattle manure to provide the energy requirements within the country are suggested.

Keywords- biogas potential; electricity; environmental benefits; dairy farms.

1. Introduction

Biomass is well known as a renewable fuel energy resource and ranks fourth providing about 14% of the world's energy needs [1].

Biogas production from animal manure has received a significant attention as an alternative energy source in recent years. This ample potential has drawn attentions after human being realized that fossil fuel reserves are being dwindled; hence they thought about converting renewable sources into different forms of energy as liquid or gas. The need to replace a high-quality renewable source of energy has been strengthened since energy costs have been raised and a lot more activities are developing.

Biogas is the by-product of the process which is referred to as anaerobic digestion. Biogas contains about 60% methane (CH_4) and 40% carbon-dioxide (CO_2). Thus, the anaerobic digester can be widely used in the production of biogas on a worldwide scale. Considering this amount of greenhouse gas percentage, GHG emissions from livestock farms should be decreased by using anaerobic digesting approach of animal manure. Moreover, the resulting methane can be contributed to the electrical energy generation, lighting, heating and cooking gas as the world would face the energy shortage crisis.

The main constituents of biogas are the CH_4 and CO_2 gas. The biogas burns very well when the methane content is more than 50%, and therefore biogas can be used as an alternative fuel.

The potential for producing biogas from animal manure especially cattles has been reviewed by several researchers [2-6]. As it is reported from similar researches, in anaerobic digesters the volatile solids (VS) breakdown in cattle waste is in the range of 15-30% [7-8].

Many studies have claimed several environmental benefits for biogas production [6, 9-12]. Providing electricity demand, heat production, reducing the odor in the surrounding zones of manure deposal, producing fertilizer and water for use in agriculture, diminishing greenhouse effects and some more advantages are apparent. Anaerobic digestion not only produces biogas, but also the produced manure with high fertilizing quality and environmentally friendly can be used as farm manure. With the less need for chemical fertilizer, farmers can cut their costs and as chemical fertilizers production process consumes energy significantly and correspondingly emits high CO_2 gas from burning fossil fuels. Biogas is a high methane fuel which is addressed as a clean fuel. In addition, biogas technology is not complicated and it does not have geographical limitations. Besides these environmental benefits, biogas production will make dairy production easier from the viewpoint of economic aspects and energy resource providing because in almost all target dairy farms, natural gas pipe lining has not been exerted. So labours can cover their energy demand for cooking, heating, cooling and other household tasks.

By considering these facts, the potential of biogas production for a sample of dairy cattle farms producing milk in Tehran province of Iran was estimated. The objective of this study was to determine the potential of biogas production using dairy cattle manure in some dairy farms of Tehran province, Iran. We believe that the results of this study are important concepts in both animal waste management and biogas production as an alternative for electricity use.

2. Material and methods

The data including the cattle manure output and the electricity use of each dairy farm located in Tehran province of Iran was measured by personal interview and observation in spring of 2011. A sample of 47 dairy farms was selected and the amount of manure output per day was measured. It should be noted here that all farms were breeding Holstein breed in their dairy farms. To convert this amount of manure to biogas, various coefficients were applied from previous studies. With assumption that, cattle dung density is 1041.3kg/m^3, the measured amount of manure was converted to the mass of manure. Hydraulic retention time (HRT) and the weight of dairy cattle were spotted as 20 days and 682 kg, respectively [11, 13].

The total solid (TS) concentration of manure is one of the main characteristics that affect how the manure is handled. The solid contents vary with the type of livestock and weight of animal. In this study TS was 16% at 30°C [14].

With the mentioned assumptions, the produced amount of manure was calculated and based on this value; the required water to be added in order to make liquid manure to feed the digester was assessed. Table 1 presents the amount of biogas production from some animal dungs [15]. In this study, we used 30 L/kg wet dung.

Table 1. Gas production potential of some animal dungs

Animals	Amount of biogas(L/kg wet dung)
Dairy cattle	30
Beef cattle	42
Swine	53
Poultry	116

As it was specified previously, biogas is worthwhile for its Methane component which has the potential to generate energy. The biogas components are given in Table 2 [15].

Table 2. Biogas compositions

Substances	Symbol	Percentage
Methane	CH_4	50-70
Carbon Dioxide	Co_2	30-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Water vapor	H_2O	0.3

The estimation of biogas production comprised three sets of calculations: manure generation, biogas generation and baseline methane emissions prior to biogas. Manure generation was calculated for dairy cattles using the following equations:

$$\text{Fresh discharge (kg/day)} = \text{Cattle dungs (m}^3\text{/day)} \times \text{Cattle dung density (kg/m}^3\text{)} \tag{1}$$

$$\text{Total solids (TS) of fresh discharge (kg/day)} = F\text{resh discharge (kg/day)} \times \text{Total solids (\% fresh discharge)} \tag{2}$$

Assuming 8% concentration of TS in influent manure;

$$\text{Total influent (kg/day)} = \text{Total solids of fresh discharge (kg/day)} \times 100/8 \tag{3}$$

$$\text{Required water (kg/day)} = \text{Total influent (kg/day)} - \text{Total solids of fresh discharge (kg/day)} \tag{4}$$

$$\text{Potential volume of biogas(m}^3\text{/day)} = \text{Total influent} \times 30\text{(L/kg influent per day)} \times 10^{-3} \tag{5}$$

$$\text{Potential volume of Methane (m}^3\text{/day)} = \text{Potential volume of biogas} \times \text{Methane in biogas} \tag{6}$$

$$\text{Potential energy generation (MJ/day)} = \text{Potential volume of Methane (m}^3\text{/day)} \times \text{Methane heating value (MJ/m}^3\text{)} \tag{7}$$

$$\text{Weight of Methane (tons/year)} = \text{Potential volume of Methane (m}^3\text{/day)} \times \text{Density of Methane (kg/m}^3\text{)} \times 365\text{ (days/year)} \times 10^{-3} \tag{8}$$

At the end, electricity requirement of operating dairy farms was discovered by observing the electricity meter of each farm and the electricity consumption of each device.

In addition to the analysis of potential biogas production as an alternate resource of electricity supply, the CO2 equivalent quantity of produced methane was reported.

$$\begin{aligned}&\text{Weight of } CO_2 \text{ equivalent (tons/year)} = \\ &\text{Weight of } CH_4 \text{ (tons/year)} \times \text{GWP } CH_4\end{aligned} \tag{9}$$

where GWP CH_4 = Global Warming Potential for $CH_4(tCO_2/CH_4) = 21$ [16].

3. Results and Discussions

The potential for extracting biogas from what is generally considered a waste in agriculture has gained increased attention in recent years.

Table 3 shows the information about the studied dairy farms. This information is included number of cattles (head), area (m^2) and the amount of cattle dungs (m^3).

Table 3. Number of cattles, area and manure production of 47 dairy farms

Breeds of cattless	Number of cattles (head)	Area (m^2)	Cattle dungs per day (m^3)
Holstein	11862	621929	243.13

According to the given information, the amount of biogas can be calculated as follow:

$$\text{Fresh discharge} = 243.13 \times 1041.3 = 253171.3 \text{ kg/day}$$

$$\text{TS of fresh dischare} = 253171.3 \times 0.16 = 40507.4 \text{ kg/day}$$

In 8% concentration of TS (To make favourable condition):

$$\text{Total influent required} = 40507.4 \times 100 \div 8 = 506342.5 \text{ kg/day}$$

Water to be added to make the discharge 8% concentration of TS:

$$\text{Required water} = 506342.5 - 40507.4 = 465835.1 \text{ kg/day}$$

Regarding the biogas production potential value is given in Table 1, we have:

$$\begin{aligned}&\text{Potential volume of biogas} = \\ &506342.5 \times 30 = 15190275 \text{ L/day} = 15190.3 \text{ m}^3 / day\end{aligned}$$

As it is provided in Table 2, the various biogas composition quantities are estimated and presented in Table 4.

Table 4. Compositions of estimated biogas production in Tehran

Gas	Percentage (%)	Gas quantity (m^3)
CH_4	55-65	7595.15
Co_2	35-45	6076.12
N_2	0-3	227.8
H_2	0-1	76
O_2	0-1	76
H_2S	0-1	76

Considering the amount of methane in the produced biogas and the heating value of methane as 36.7 MJ m^{-3}, the energy amount can be calculated as:

As the result of this study, electricity use of 1395.8kWh/day was measured for the whole target dairy farms. Evidently, this electricity consumption can be completely covered by the received biogas energy and the excess amount would be a good source of energy for heating, cooking, lighting applications.

Assuming the Methane density to be 67×10^{-8} kg/m^3, the weight of Methane gas in a year was calculated as following:

$$\begin{aligned}&\text{Weight of Methane} = \\ &7595.15 \times 67 \times 10^{-8} \times 365 \times 10^{-3} = 0.0018 \text{(tons/year)}\end{aligned}$$

$$\text{Weight of } CO_2 \text{equivalent} = 0.0018 \times 21 = 0.04 \text{(tons/year)}$$

It is obvious that for the selected dairy farms the amount of CO_2 equivalent emissions is not such a lot. Hence, there is no concern about environmental impacts on GHG in biogas production.

The lack of previous studies on biogas potential in dairy farms of Iran, the results of this study were not compared with any research results. In a study carried out by Sedaghat Hosseini [17] the biogas production in poultry was estimated in Iran and results showed that the generated gas can be employed as an electricity energy resource of 984.17 MJ in winter and 1467.93 MJ in summer which implied that in summer and winter, about 43.5% and 41%, respectively of electrical energy can be provided.

4. Conclusion

The unutilized potential for biogas production in Iran lies in the dairy farms. The recommendation of the present study is obligatory utilization of potential of biogas production from livestock wastes (dairy cattle) for providing an alternative energy resource or it can be sold to the local electric utility. Theoretically, if all dairy manure resources in the zone could be utilized, 77.4 MWh of electricity could be generated from 7595.15 m^3/day Methane gas. In Iran, it is necessary to have some training programs for the importance of biogas production in the enterprises.

Perhaps after making alternative energy resources, the most significant impact of the anaerobic digestion of dairy cattle manure with biogas capture is the reduction in the emission of methane, a greenhouse gas with 21 times the heat-trapping capacity of carbon dioxide to the atmosphere; hence it is suggested to follow this subject in the future studies. To ensure farmers against the benefits of generating alternative energy sources from biogas, it is recommended to promote the extension programs or establish sample farms with the proposed technology in this research or other similar studies.

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