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# BIOGAS PRODUCTION FROM ANIMAL MANURE

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## Abstract

An experimental study worked on a model biogas production unit which has 0.5 $m^3$ fermentation tank capacities of a breeding farm in the Urla district of Izmir/Turkey. The farm animal quantity is 70 cattle and 1400 chicken. Animal wastes (poultry manure and bovine animals manure) were anaerobically fermented in the tank. It is known in literature, the optimum fermentation occurs at 298-313 K temperatures. In this respect, experimentation was performed at summer season and average regional temperature was 307 K and so reaction does not require the extra heating for the optimization of process. Biogas production potential from bovine animal and poultry manure was separately studied. Firstly, 350 kg bovine animal manure blend (175 kg manure+175 kg water) filled to the tank and the process occurred. Secondly, 375 kg poultry manure blend (50 kg manure+325 kg water) was filled to the tank and the processes done. Then the biogas production rates was evaluated and compared for two processes. Results showed that daily 6.33 $m^3$ and 0.83 $m^3$ biogas productions were obtained from fermentation of bovine animal manure and poultry animal manure. Lower heating value of natural gas was known 34,000 kJ/$m^3$, and biogas LHV value was predicted 21,000 kJ/$m^3$ by the 62% $CH_4$ content. By using biogas as a fuel to the heating or energy systems instead of natural gas about 0.35 \$/$m^3$ energy cost is saved.

Keywords: Biogas, Anaerobic fermentation, Animal manure.

## 1. Introduction

The lack of energy sources in this century stimulates the researchers to research alternative energy sources. In recent years, studies on the waste recovery and alternative energy sources have been popular in the scientific area. Many studies argue about biogas production from different type of organic wastes and plants. Obiukwu and Nwafor (2014) investigated the production of biogas, an alternative

**Nomenclatures**

| | |
|---|---|
| C | Carbon |
| $CH_4$ | Methane |
| N | Nitrogen |
| *pH* | Potential of Hydrogen |

**Abbreviations**

| | |
|---|---|
| COD | Chemical oxygen demand |
| CSTR | Continuous stirred tank reactors |
| DM | Dry matter |
| LHV | Lower heating value |
| ODM | Organic dry matter |
| VS | Volatile solids content |

source of energy from animal wastes in the laboratory scale. Results showed that biogas containing the methane content of 65% was produced at temperature of 310 K proven as most efficient for stable continuous digestion process [1]. Isci and Demirer (2007) studied the anaerobic treatability and methane generation potential of three different cotton wastes namely, cotton stalks, cotton seed hull and cotton oil cake were determined in batch reactors. For this purpose biochemical methane potential experiments were performed for two different waste concentrations, namely 30 and 60g/l. The results revealed that, approximately 65, 86 and 78 mL $CH_4$ were produced in 23 days from 1g of cotton stalks, cotton seed hull and cotton oil cake in the presence of basal medium, respectively [2]. Okeh et al. (2014) studied the laboratory scale biogas production from rice husks generated from different rice mills was investigated using cow rumen fluid as a source of inoculum. Feedstock to water dilution ratio of 1:6 w/v and initial pH 7 gave the maximum biogas yield of 382 and 357mL/day, respectively. The maximum values of biogas production rate were 30 and 69 mL/day for the control and poultry droppings, respectively, after two days while urea gave 8 mL/day on day four [3]. Mashad and Zhang (2010) studied the biogas production potential of different mixtures of unscreened dairy manure and food waste and compared them with the yield from manure or food waste alone. The methane yields of fine and coarse fractions of screened manure and unscreened manure after 30 days were 302, 228, and 241 L/kg, respectively.

Approximately 93%, 87%, and 90% of the biogas yields could be obtained, respectively, after 20 days of digestion. Average methane content of the biogas was 69%, 57%, and 66%, respectively [4]. Liu (2009) et al. studied the biogas and methane yields of food and green wastes and their mixture were determined using batch anaerobic digesters. The mixture was composed of 50% food waste and 50% green waste, based on the volatile solids initially added to the reactors. The biogas yields were 430, 372 and 358 mL/g, respectively, and the methane yields were 245, 206, and 185 mL/g, respectively [5].

Abubakar and Ismail (2012) investigated the effectiveness of cow dung for biogas production. The averaged cumulative biogas yield and methane content observed was 0.15 L/kg VS added and 47%, respectively [6]. Alvarez and Liden (2009) studied the biogas production in anaerobic digestion in farm-scale units is typically performed under mesophilic conditions when used for producing domestic fuel and stabilizing animal waste for the use of digested manure as a fertilizer. The results suggest that in a system digesting a mixture of llama-cow-sheep manure at low temperature (291–298) K. The methane yields obtained in the mixture experiments were in the range 0.07–0.14 $m^3$/kg added, with a methane concentration in the gas of between 47 and 55% [7].

Imam et al. (2013) investigated biogas production from fermentable materials were selected as cow dung, poultry waste and water hyacinth. Percentage of methane content (the main constituent) in biogas produced from different fermentable materials is almost the same [8]. Castrillon et al. (2013) studied biogas production from cattle manure by adding food waste and crude glycerine from the biodiesel industry as co-substrates. It was observed that methane content in biogas up to 78% [9]. Owamah et al. (2014) investigated the optimization of biogas production and quality from chicken droppings by anaerobic co-digestion with Cymbopogon citratus. Obtained results indicated that chicken droppings produced on the average 1.8 L/kg/day of biogas, co-digestion of chicken droppings [10]. Westerholm et al. (2012) evaluated as substrate for biogas production in five mesophilic laboratory-scale biogas reactors, operating semi-continuously for 640 days. The methane yield at an organic loading rate at 2.8g VS/(L x day) and a hydraulic retention time of 45 days with a substrate mixture 85 % whole stillage and 15 % manure (based on volatile solids) was 0.31NL $CH_4$/g VS [11].

Xie et al. (2012) studied the anaerobic co-digestion of the solid fraction of separated pig manure with dried grass silage in three identical continuously stirred tank reactors at 308±1 K. Post-methane production potentials of digestates ranged from 38% to 41% of total methane production potentials of the feedstock [12]. Quiroga et al. (2014) presented a study of the effect of applying ultrasound pre-treatment in the production of methane when co-digesting mixtures of cattle manure with food waste and sludge. It was found that up to 67% increase in methane yield at $55^0$C and 31% at $37^0$C [13].

Sebastian et al. (2014) the anaerobic digestion of municipal sewage sludge with swine manure and poultry manure was undertaken. The experiments showed that a 30% addition of swine manure to sewage sludge significantly increased biogas production by nearly 40%, compared to that with sewage sludge alone [14]. Zhang et al. (2013) assessed the anaerobic co-digestion of food waste and cattle manure, in order to identify the key parameters that determine the biogas and methane yield. The C/N ratio and the higher biodegradation of lipids might be the main reasons for the biogas production improvement [15]. Castrillion et al. (2013) the aim of the present research work was to optimise biogas production from cattle manure by adding crude glycerine from the biodiesel industry. Ninety percent COD removal and 0.59 $m^3$ $CH_4$/kg VS (56.5 $m^3$/t waste) were achieved [16]. Rico et al. (2011) analysed the performance of a 1.5 $m^3$ volume CSTR digester processing the screened liquid fraction of dairy manure. The digestate yielded an attractive amount of gas, 28.4% of that produced in the CSTR, which implies that the digestive tank should be covered to capture its residual methane yield [17].

This paper discuss about the experimental investigation of the biogas production with the animal manures at a breeding farm which has the animal capacity is 70 cattle and 1400 chickens in the Urla district of Izmir.

## 2. Experimental Procedure

Anaerobic fermentation reaction is dependent on the different parameters such as temperature, mixing, reaction period, raw material and quantity. Temperature and pH value of the blend was measured by Testo 435 multifunction and Mettler Toledo pH measurement devices. Temperature and pH value of tank was measured in 303-308 K and 6.6-7.1 pH. This study was performed with the animal wastes (poultry manure and bovine animals manure) for specified quantities were given in Table 1.

**Table 1. Annual Manure Quantity.**

| Waste | Mass (kg/day) | Animal | Total Wet Manure Quantity (kg/day) | Annual Quantity (kg/year) |
|---|---|---|---|---|
| **Bovine animals manure** | 25 | 70 | 175 | 63,875 |
| **Poultry manure** | 0.036 | 1400 | 50 | 18,250 |

The optimum fermentation reaction to obtain maximum amount of gas requires the suitable conditions and elimination of external negative effects like external impurities, contamination with atmosphere, dust and leakage water from the environment. Fermentation reaction tank was occurred in a 0.5 $m^3$ tank shown in Fig. 1. The gas sampling line was shown in Fig. 2.

**Fig. 1. Fermentation Tank.**

**Fig. 2. Biogas Sampling Line.**

Experimentation was performed at summer season while the mesophilic temperature was between 298 K to 313 K ranges to obtain optimum fermentation reaction. Two types of animal waste (bovine manure and poultry manure) were fermented separately to obtain biogas. In the first experimentation, the bovine manure was mixed with water one to one rate like 175 kg bovine manure and 175 kg water was mixed and 350 kg mixed material was filled to the tank. Experimentation was performed about 20 days. In the second case, the poultry manure was mixed with water at rate of 1/6.5 as 50 kg manure and 325 kg water was mixed and filled the tank. According to the experimental study obtained biogas quantity per day was given in Table 2.

**Table 2. Daily Biogas Production Quantity.**

| Waste | Total Wet Manure Quantity (kg/day) | DM (%) | ODM (%) | Biogas producing rate ($m^3/kg_{ODM}$) | Biogas quantity ($m^3$/day) | Fertilizer (kg/day) |
|---|---|---|---|---|---|---|
| **Bovine animals manure** | 175 | 8.44 | 72.39 | 0.05 | 6.33 | 145 |
| **Poultry manure** | 50 | 71.92 | 23.7 | 0.07 | 0.83 | 47.5 |

***DM = Dry material, *ODM = Organic dry material**

Predicted $CH_4$ content of biogas which is produced by the cattle and poultry manure is about 62%. LHV of $CH_4$ is known about 34,000 kJ/m$^3$. Due to this LHV value of biogas is about 34.000×0.62=21,000 kJ/m$^3$.

Figure 3 presents the liquid end product of fermentation process. Degassed liquid end product is beneficial fertilizer to the farming plants.

4.7 kWh of electricity could be produced by 1 $m^3$ biogas [18]. According to this information biogas usage to produce electricity means the recovery of the waste energy to the economy. The cost of this waste recovery is about 0.55 $/$m^3$.

**Fig. 3. Liquid Fermented Product.**

## 3. Results and Discussion

Biogas production potential by usage of the poultry and bovine manure was argued in this paper. Experimentations were carried out at a farm, which includes 1400 chicken and 70 cattle, in summer season to provide optimum fermentation reaction conditions. According to the results of separate fermentation reaction experimentations of poultry and bovine manures in a 0.5 $m^3$ fermentation tank orderly about 0.83 $m^3$ and 6.33 $m^3$ biogas was obtained. The end product of fermentation reaction was the fertilizer to dress the farm fields. About 47.5 kg and 145 kg fertilizer was formed at the end of the fermentation reaction. By this study economically, the animal waste manure was used to obtain an alternative energy source biogas which has the lower heating value of 21,000 kJ/$m^3$ and so usage of this energy source instead of the natural gas which has the lower heating value 34,000 kJ/$m^3$ is about 0.35 $/$m^3$ saving potential was determined. Additionally, waste animal manure was turned to the more valuable and beneficial fertilizer to dress the farming fields at the end of this process.

## 4. Conclusions

An investigation has been made to determine the biogas production potential from poultry manure and bovine animal manure.

- By the fermentation reaction of animal waste manure an alternative energy source biogas which has the lower heating value of 21,000 kJ/$m^3$ is about daily 0.83 $m^3$ and 6.33 $m^3$ biogas was obtained and usage of this energy source instead of the natural gas which has the lower heating value 34,000 kJ/$m^3$ is about 0.35 $/$m^3$ saving potential was determined.
- Biogas usage to produce electricity means the recovery of the waste energy to the economy. The cost of this waste recovery is about 0.55 $/$m^3$.

- About 47.5 kg and 145 kg higher quality fertilizer was formed at the end of the fermentation reaction and so animal wastes turned into beneficial product to the farming.

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