Production of Biogas as a Source of Renewable Energy through Co-Digestion of Agricultural Residues with Poultry Manure

Burak Demirel[1], N. Pınar Göl [2], Turgut Tüzün Onay[3]

Abstract — The objective of this laboratory-scale experimental work is to investigate the biogas production potential of two different substrates, namely poultry manure and a chosen agricultural residue (sun flower hulls), via mesophilic anaerobic co-digestion process, using batch-scale systems. This paper summarizes the preliminary results from the ongoing experiments.

Keywords — Agricultural residues, Anaerobic digestion, Biogas, Poultry manure, Renewable energy

1 INTRODUCTION

Utilization of sustainable energy technologies has gained extreme importance recently, in order to mitigate global climate change. Among these sustainable energy technologies available, biological production of biogas, namely the anaerobic digestion process, from biomass (such as manure, agricultural residues, energy crops, organic fraction of municipal solid wastes, sludge) offers significant advantages which can be employed to reduce CO_2 emissions that trigger the greenhouse effect [1-3]. Simply put, biogas can be used for heating, electricity production, as a substitute of natural gas and as fuel in vehicles.

Turkey's recent developments in industrial and agricultural sectors are obviously promising. As industrial developments increase, the energy demand consequently increases. Turkey's energy consumption has been growing much faster than its energy production, thus making Turkey an energy importing country. There is no doubt that the increase of foreign dependence on energy results in significant political concerns. If we consider the potential of renewable energy sources, Turkey can easily manage to solve this foreign dependency issue. Besides, the whole world focuses on energy alternatives due to global warming concerns and future limitation of fossil fuels.

Turkey has a remarkable amount of renewable energy sources. Apart from the renewable energy sources, such as wind, hydro, solar, geothermal, biomass is an another option that can be used as an alternative to fossil fuels, since energy generated via biomass lessens air emissions, reduces the amount of waste sent to landfills and at the same time decreasing the dependence on foreign oil sources. In Turkey, biogas production potential is forecasted to be approximately 1.5-2 Mtoe (million ton oil equivalent) [4]. Therefore, in order to produce renewable energy and to dispose agricultural and animal wastes properly, biogas technology seems to be an important alternative for Turkey. It is also expected that the recent revision on the Regulation on the Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy (Law No: 6094, December 2010), which increased the feed-in-tariff, will draw more attention on application of biogas technology in Turkey.

The objective of this batch-scale experimental study is to investigate the potential of biogas generation via anaerobic co-digestion of the chosen agricultural residue, namely the sun flower hulls and poultry manure. This paper presents the preliminary results from the ongoing experiments.

2 MATERIALS AND METHODS

2.1 The Substrates

During the experimental work, the agricultural residue (sun flower hull) was obtained from a factory located in Edirne (Marmara Region). The characteristics of the agricultural residue are presented in Table 1. The poultry manure was obtained from Bandırma (Marmara Region). The characteristics of the poultry manure are presented in Table 2. The seed sludge used in batch experiments was obtained from a yeast factory located in Izmit (Marmara Region). The

1. *Burak Demirel is with the Institute of Environmental Sciences, Bogazici University, 34342 Istanbul Turkey E-mail: burak.demirel@ boun.edu.tr*
2. *N. Pınar Göl is with the Institute of Environmental Sciences, Bogazici University, 34342 Istanbul Turkey E-mail:pinargol@gmail.com*
3. *Turgut Tüzün Onay is with the the Institute of Environmental Sciences, Bogazici University, 34342 Istanbul Turkey E-mail:onayturg@ boun.edu.tr*

seed sludge had a pH of around 7.1-7.4, and the total solids (TS) and total volatile solids (TVS) contents were 21 and 95 %, respectively.

Table 1. The characteristics of sun flower

Parameter	Unit	Range
pH		5.1 – 5.4
Total Solids (TS)	%	89.1-91.6
Total Volatile Solids (TVS)	%	96.7-98.1
Total Kjeldahl Nitrogen (TKN)	mg/kg	2.6 – 10.1
Phosphate	mg/kg	4.1 – 9.2
Moisture	%	8.6 – 9.1
Potassium (K)	mg/l	360.5-681.5
Magnesium (Mg)	mg/l	27.2 – 38.9
Sodium (Na)	mg/l	4.8 – 7.8
Calcium (Ca)	mg/l	40.9 – 44.5
Iron (Fe)	mg/l	0.02-2.80
Nickel (Ni)	mg/l	0.04-0.05
Zinc (Zn)	mg/l	0.08-0.09
Copper (Cu)	mg/l	0-0.08

Table 2. The characteristics of poultry manure

Parameter	Unit	Range
pH		5.2 – 5.9
Total Solids (TS)	%	44.9-49.8
Total Volatile Solids (TVS)	%	86.1 -89.3
Total Kjeldahl Nitrogen (TKN)	mg/kg	14.4 – 30.8
Phosphate	mg/kg	48.1 – 81.0
Moisture	%	36.1 – 50.1
Potassium (K)	mg/l	1206 - 1499
Magnesium (Mg)	mg/l	121.1 – 193.7
Sodium (Na)	mg/l	131 - 142
Calcium (Ca)	mg/l	370.7 – 385.5
Iron (Fe)	mg/l	0.2 – 3.7
Nickel (Ni)	mg/l	0.2 – 0.3
Zinc (Zn)	mg/l	3.6 – 4.4
Copper (Cu)	mg/l	0.1 – 0.2
Cobalt (Co)	mg/l	0.02-0.15

2.2 Experimental Set-Up

The batch experiments were conducted under mesophilic conditions at 35°C. As batch reactors, 1 litre borosilicate glass bottles were used. Active working volume was 500 ml. After filling with pre-determined amounts of seed sludge, poultry manure and sun flower hulls, the batch reactors were sealed and placed in a temperature controlled water bath. In each set, the ratio (w/w) of poultry manure to sun flower is increased. During batch-studies, the temperature was monitored continuously. Biogas production was measured daily using inverted graduated cylinders and measured values were corrected for STP.

2.3 Analytical Methods

Total Kjeldahl nitrogen (TKN), solids (TS, TVS), phosphate, moisture and alkalinity analyzes were performed according to Standard Methods [5]. The pH was monitored using a WTW pH 330 pH-meter with a WTW SenTix probe. The composition of biogas (CH_4, CO_2) was measured by a gas chromatograph (Agilent). Analyzes of metals were performed with a Perkin Elmer Analyst 300 AAS.

3 RESULTS

The results of two batch experiments, namely set-1 and set-2, are summarized in this section of this paper. The cumulative biogas production for both set-1 and set-2 versus time is shown in Figure 1 below.

In set-1, the percentage of poultry manure co-digested with sun flower was 6.3 % (w/w). The cumulative biogas (corrected for STP) and methane productions were 1934 and 518 ml, respectively, for set-1. The alkalinity value was 5687 mg $CaCO_3$/l, indicating a high buffering capacity of the system. The ratio of biogas production to volatile solids (VS) added was 0.022 litre biogas/VS added.

In set-2, the percentage of poultry manure was increased to 12.5 % (w/w). For set-2, cumulative biogas (corrected for STP) and methane productions were 1568 and 804 ml, respectively. Increase in the amount of poultry manure seemed to affect biogas production adversely, however, methane percentage of biogas produced in set-2 increased. The alkalinity value was measured to be 10764 mg $CaCO_3$/l, also indicating a high buffering capacity of the system for set-2. The ratio of biogas production to volatile solids (VS) added was 0.018 litre biogas/VS added. The methane (CH_4) composition in biogas was 51 % for set-2.

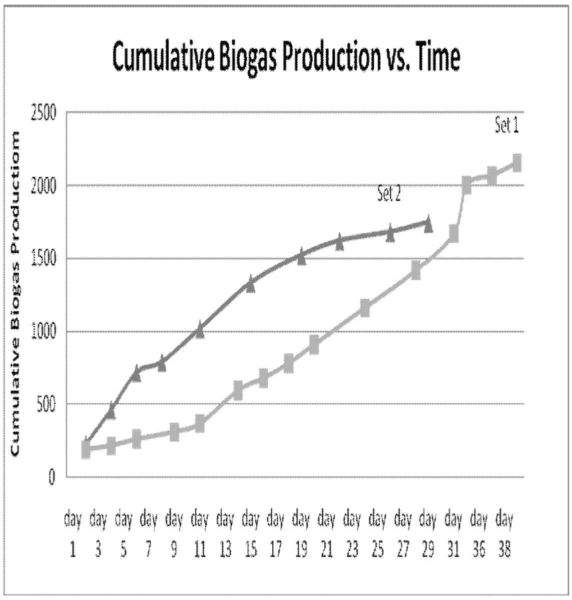

Fig. 1. The cumulative biogas production versus time for set-1 and set-2.

The digestate was also analyzed for both set-1 and set-2, in terms of heay metal content, in order to determine if the digestate resulting from co-digestion of sun flower residue with poultry manure is suitable for application on land. According to Turkish Soil Polution Control Act, the amounts of lead, cadmium, chromium, copper, nickel, zinc and mercury in sludge have to comply with the limits set. Therefore, lead, cadmium, chromium, copper, nickel, zinc and mercury were measured in the digestate for both set of experiments. The results of these measurements and their comparison with the Turkish Soil Polution Control Act is shown in Table 3.

Table 3. Analysis of the digestate

Heavy Metals	Limit Value *	Set-1	Set-2
Lead	750	0,00	0,00
Cadmium	10	0,00	0,00
Chromium	1000	0,27	0,06
Copper	1000	0,25	0,12
Nickel	300	0,51	0,84
Zinc	2500	1,37	0,81
Mercury	10	1,34	0,16

* Turkish Soil Pollution Control Act; all the units are in mg/kg.

According to the preliminary results given above, the digestate from anaerobic co-digestion of agricultual residue and poultry manure can be applied to the land.

The experiments of this batch-scale study are still being conducted at the Institute of Environmental Sciences of Bogazici University.

4 DISCUSSION

There exist recent studies in literature covering anaerobic co-digestion of various agricultural residues with manure in order to produce biogas as a source of renewable energy [6-9]. Anaerobic co-digestion seems a valuable option to treat agricultural residues/wastes and to produce renewable energy from them.

The selected agricultural residue for this study, namely the sun flower, has a high VS content, however, contains low amounts of N and P as macro-nutrients. In addition, the sun flower hulls are reported to contain high amounts of lipids and cellulose by weight [10]. These two factors may affect VS degradation and particularly methane production from the sun flower adversely. Addition of poultry manure, which contains relatively higher amounts of both N and P, will provide required amounts of these macro-nutrients to the batch digestion system. Poultry manure also contains relatively higher amounts of Mg, Ca, P and Na, that will affect biodegradation process in a positive manner. Therefore, in each set, the ratio of manure to agricultural residue will be increased to observe whether the poultry manure addition will increase biogas and methane production efficiency. Lower biogas yields from set-1 and set-2 might have probably resulted from the composition of the sun flower hull (in terms of its lipid and cellulose content).

The digestate resulting from batch studies seemed to contain very low amounts of heavy metals, according to the Turkish Soil Pollution Control Act. Therefore, the preliminary results showed that it could be applied to the land as a fertilizer.

5 CONCLUSIONS

Anaerobic co-digestion of agricultural residues with manure is a valuable option to produce renewable energy (biogas), particularly in rural regions. The preliminary results of this ongoing experimental study shows that sun flower hulls can be co-digested with poultry manure to produce biogas and the digestate can then further be used as fertilizer in land applications. The chemical composition of sun flower hulls probably resulted in lower biogas yields. However, increasing proportions of poultry manure can positively affect methane generation from this co-digestion system, since the poultry manure is rich in terms of both macro and micro nutrients.

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