The Effect of Temperature on Methane Productivity of Municipal Solid Waste in Anaerobic Digester

Azadeh Babaei,1 Jalal Shayegan,1 Anis Roshani2

Jalal Shayegan1

1Sharif University of Technology, Tehran, Iran and 2Azad University of Tehran, Tehran, Iran

Short Abstract
The amount of municipal solid waste (MSW) generated in Iran is around 60000 ton/day of which more than 70% is organic wastes. The objective of this study was to optimize the applications of anaerobic digestion for the treatment of municipal organic wastes. In order to obtain basic design critera for anaerobic digester of MSW, the effect of different temperatures on the performance of anaerobic digestion of municipal solid waste (MSW) was investigated in pilot-scale experiments. In the investigation, digester temperatures were set between 25-34°C. Digestion with temperature in these range resulted in biogas yield of 0.23-0.33 m3biogas/ kg VS, with a methane content in the biogas of 52.4-62.6%. The methane content and yield decreased with reduction of digestion temperature. However this reduction was almost negligible from 34°C to 30°C. Based on the data obtained from this study, temperature in the range of 30-34°C is suggested as a base for design purpose and successful implementation of anaerobic digestion as the method of waste treatment leads to the regional utilization of renewable energy resources, energy requirements and costs.

Keywords: Anaerobic digestion, Biogas, Municipal solid waste, Temperature

Introduction
The amount of municipal solid waste (MSW) generated in Iran is around 60000 ton/day of which more than 70% is organic wastes. The easy biodegradable organic matter of vegetable waste with high moisture content facilitates its biological treatment and shows the trend of these wastes for anaerobic digestion (Bouallagui et al., 2003). In light of rapidly rising costs associated with energy supply and waste disposal and increasing public concerns with environmental quality degradation, conversion of food wastes to energy is becoming a more economically viable practice, Anaerobic digestion has become an established and proven technology as a means of managing solid organic waste (De Baere, 1999). Besides generating biogas for energy use, the process also destroys pathogens and produces stabilized material to be used as fertilizer in land applications. Anaerobic digestion may lead to environmental benefits with regard to waste treatment, pollution reduction, energy production and improvements in agricultural practices (Chynoweth et al., 2001). There are a large number of factors which affect biogas production efficiency such as environmental conditions like pH and temperature, inhibitory parameters like high organic loading, formation of high volatile fatty acids and inadequate alkalinity. Volatile solids input, digester temperature and mixing are operational parameter that have a strong effect on digester performance (Forster et al., 2008).

The temperature of slurry affects the success of the digestion process, as the activities of the anaerobes causing waste decomposition are highly temperature dependent. The rate
of decomposition and gas production is sensitive to temperature, and, in general, the process becomes more accelerated at higher temperatures (Steadman, 1975). The optimum digester temperature setting, considering both the potential biogas yield and heat requirement, is one of the most critical factors for the economically viable digester operation. Despite the importance of temperature in achieving efficient substrate conversion, there is no clear picture about the effects of this parameter on anaerobic digestion of MSW. Therefore, there is a need for further research on evaluating the optimum temperature. In this study the effect of different temperature within mesophilic ranges (25-34 °C) on digestion of MSW was investigated to obtain design criteria for economical anaerobic digesters in Iran.

Methods

Feedstock preparation

The municipal waste was daily collected from five selected routes and screened to remove the coarse contaminants. Then the waste was shredded by an ordinary kitchen blender. The initial solid content of MSW was 26%, with total volatile solids (VS) of about 85%. The COD/N ratio of MSW is being around 22 and therefore, no nitrogen was added to the reactor. The anaerobic sludge from Ekbatan wastewater treatment plant was added as seed.

Experimental device

The digester experiments were carried out in semi-continuously digester with a total capacity of 70 l. The reactor was fitted with a top plate, which supported the mixer, mixer motor, gas sampler. Sampling valves were located at positions corresponding to the top, middle and bottom layer of digester contents.

The reactor had one outlet at the bottom for effluent removal. The contents of the reactor were mixed as controlled by a timer, which were activated for 15 min every 45 minutes. The digester was operated in mesophilic condition (25-34°C).

Digester operation

The purpose of this study was to obtain the basic design criteria; mainly biogas yields at different temperatures for a mesophilic MSW digester. For this study Semi-continuous experiments were conducted at organic loading rates of 1.4 kg VS/m³.d with a fixed hydraulic retention time of 25 days in all runs (Babaee et al., 2011). Retention time of 25 days was maintained by feeding 2.4 L of feedstock and removing 2.4 L of effluent daily. In the investigation, digester temperatures were set at 25, 28, 30 and 34°C.

Analyses

Daily biogas production was measured by using a water displacement method. Biogas samples were taken periodically from the gas collection lines and analyzed for methane using gas chromatography. Total solids (TS), volatile solids (VS), pH, alkalinity were determined according to the APHA Standard Methods (APHA, 1998). Total nitrogen (TN) was estimated by the Kjeldahl method (Greenberg et al., 1992).

Results and Discussion

Biogas Production

According to the results, the total gas production was greatest at 34 °C, and a temperature decrease from 34 to 25 °C resulted in a decreased biogas production (40% higher at 34 °C relative to 25 °C). The results at 30 and 34 °C were almost similar, but was much higher compared to that of 25
°C. There was a faster degradation at the higher temperatures, as shown in Fig. 1. The biogas production reached its peak value of 45 l/d on 20th day and 30 l/d on 27th day at 34 and 25 °C, respectively. For this reason the required times to complete the digestion of MSW at 34 °C was lower than 25 °C.

Fig. 1. Biogas production at different temperature

Therefore, approximately 20-25 days seems to be the minimum for optimal digestion of MSW for a digester in which somewhat larger particles can be fed occasionally. The biogas composition differed according to digestion temperature, with methane contents in the biogas of 62.6%, 61 %, 56.18% and 52.14% at 34, 30, 28 and 25 °C, respectively, but these differences were statistically not significant between 30-34°C. The changes of methane content were corresponded to the biological biogas-producing phase that dependent on pH value. These findings are in agreement with the results of Chae (2007) on the anaerobic digestion of swine manure under mesophilic conditions. The variation of alkalinity and pH is shown in Fig.2.

![Fig. 2. Values of alkalinity and pH on various temperature](image)

From these data it can be observed the pH values in the reactor operated at higher temperatures, are higher compared to that operated at lower temperature. The pH of the digester liquid and its stability as well comprises an extremely important parameter, since methanogenesis only proceeds at high rate when the pH is maintained at 7.6-8. The rate of biogas and methane production declines at pH values below 7.6 at 28 °C. The pH of effluent leachate from the continuous digester remained steady state to the range of 7.6 - 8.0 at 34 and 30°C which shows that the system was well buffered and the biogas production was not obvious between 34 and 30 °C. When the temperature rate was decreased to 28 and 25 °C, the pH value dropped from 7.6 and reached to lower value of 7.2. For this reason biogas production was
reduced. These results were in agreement with previous results that showed an improvement in the biogas yields with increasing temperature (Hobson et al., 1980).

**Performance of anaerobic digestion**

As the temperature rate was decreased, the COD concentration in the leachate increased. This can be explained that there was higher hydrolysis but less methanogenesis because methanogenic bacteria are sensitive to temperature and pH change and their activities was low at 25°C. As temperature was decreased, VS and COD degradation decreased (Fig. 3).

![Graph showing VS and COD degradation on various temperatures](image)

**Fig. 3.** VS and COD degradation on various temperatures

Highest VS degradation value of 86% was achieved when operating at 34°C. On the other hand, while temperature decreased to 25°C, VS removal was decreased to 76%. Comparably, this VS reduction was similar with result found by Castillo et al. (2006) who reported that VS reduction of 77.1% was obtained with the retention time of 25 days at 25°C.

The relative biogas and methane yield at different temperatures in the digestion of MSW is shown in Fig. 4. The biogas yield was influenced by temperature in the range of 25–34 °C, but was not linear within the tested range. According to the results, greatest biogas and methane yield of 0.33 m³biogas/kg VS and 0.21 m³CH₄/kg VS were obtained at 34 °C. This was relatively high compared to the methane yields normally achieved, 0.4 m³biogas/kg VS from organic fraction of MSW at 35 °C (Nguyen et al., 2007).

![Graph showing biogas and methane yield versus temperature](image)

**Fig. 4.** Biogas and methane yield versus temperature

The difference in the methane yield was not obvious between 35 and 30 °C; approximately 90% of the methane produced at 35°C was still produced at 30 °C. In contrast, the digestion proceeding at a temperature of 25 °C showed only 70% of that at 35 °C. Balance between the energy demands to heat the digester for higher gas production must be simultaneously
considered when deciding the optimum operating temperatures. Therefore, with respect to the net energy recovery, the optimum temperature in this project might be around 30°C. Furthermore, temperature has a strong effect on the concentration of free ammonia (NH$_3$), the real inhibitor rather than ammonium (NH$_4^+$) (Hashimoto, 1986). Free ammonia concentration increases with increasing temperature, by influencing the equilibrium. Therefore, careful consideration is required when increasing the digestion temperature for the purpose of enhancing the methane yield due to the simultaneous increase in the ammonia inhibition.

**Conclusion**

Results from temperature changes showed that temperature had some influence on process performance and methane production in semi-continuously reactors treating MSW. Considering the characteristics of the high-moisture solid waste, anaerobic digestion represents a feasible and effective method to convert the waste to biogas fuel. In the mesophilic temperature range, the higher the temperature, the better the methane yield. The yields at 30 and 35°C were similar, but were quite high compared to that at 25°C. However, this result does not mean the higher temperature the more optimal, due to the larger energy requirement at higher digesting temperatures. Therefore, careful consideration of the net energy balance between the increased heating energy demands and improved additional methane production at higher operating temperatures must be simultaneously taken into account when deciding the economical digesting temperature. Based on the data obtained from this study, temperature in the range of 30-34°C is suggested as a base for design purpose. Successful implementation of anaerobic digestion as the method of waste treatment leads to the regional utilization of renewable energy resources, as well as the disposal of high moistening content of MSW.

**References**


