

# Anaerobic Digestion of Vegetable Waste

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Fruit and vegetable wastes are produced in large quantities in Iran, and constitute a source of nuisance in municipal landfills. The objective of this study was to optimize the applications of anaerobic digestion for the treatment of municipal organic wastes. We studied the effect of organic loading rates on anaerobic digestion of vegetable wastes. The complete-mix, pilot-scale digester with working volume of 70 l was used. The experiments were conducted at 34°C with a fixed hydraulic retention time of 25 days. The digester was operated at different organic feeding rates of 1.4, 2 and 2.75 kg VS/(m<sup>3</sup>.d). The biogas produced had methane composition of 49.7- 64% and biogas production rates of 0.12-0.4 m<sup>3</sup>/(kg VS). The reactor showed stable performance with highest biogas production (0.4 m<sup>3</sup>/kg VS) and VS reduction of around 88% during loading rate of 1.4 kg VS/(m<sup>3</sup>.d). The chemical oxygen demand (COD) reduction, VS removal and methane concentration in biogas was decreased when the organic loading rate was increased. Based on the data obtained from this study, OLR of 1.4kg VS/(m<sup>3</sup>.d) is suggested as design criteria with biogas production rate of 0.4 m<sup>3</sup>biogas/(kg VS).

## 1. Introduction

Fruit and vegetable wastes are produced in large quantities in markets, and constitute a source of nuisance in municipal landfills because of their high biodegradability (Virturia et al., 1989). The amount of MSW generated in the Tehran is around 4000 ton/day, and contains more than 70% of organic wastes. The easy biodegradable organic matter content of vegetables waste with high moisture facilitates their biological treatment and shows the trend of these wastes for anaerobic digestion (Bouallagui et al., 2003). Anaerobic digestion is becoming more and more attractive for the treatment of high strength organic wastes such as municipal solid waste, since it produces renewable energy, methane, and valuable digested residues, liquid fertilizer and soil conditioner (Angelidaki and Ahring, 1994). There are a large number of factors which affect biogas production efficiency such as environmental conditions like pH, temperature, inhibitory parameters like high organic loading, etc. Volatile solids input, digester temperature and retention time are operational parameter that have a strong effect on digester performance (Forster et al., 2008). Since municipal waste characteristics various from country to country as well as other operating conditions, pilot-scale experiments are required to obtain suitable design criteria. The aims of this study were to investigate the

influence of OLR on performance and treatment efficiency (based on volatile solids removal) of vegetable waste digestion in semi continuous slurry digester.

## 2. Materials and Methods

### 2.1 Experimental layout

The digester experiments were carried out in a semi-continuously pilot-scale with a total volume of 70 L. Fig.1 illustrates the experimental set-up. The reactor was fitted with a top plate, which supported the mixer, mixer motor, gas sampler. Sampling ports and effluent 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 was activated for 15min every 45 minutes. Reactor temperature was maintained at 34 °C.

### 2.2 Waste characteristics

The vegetables wastes were collected from food markets in Tehran every week. The total initial solid concentration of vegetables waste was 8%, with a total volatile solids (VS) content of about 97%. The COD/N ratio of vegetables waste is balanced, being around 30 and therefore, no nitrogen was added to the reactor. In fact the optimum C:N ratio for microbial activity involved in bioconversion of vegetable biomasses to methane is 25-30 (Kivaisi and Mtila, 1998). The anaerobic sludge from Ekbatan wastewater treatment plant was added as seed.

### 2.3 Anaerobic digester operation

Experiments were operated in semi-continuous mode with daily feeding. Dry semi-continuous anaerobic digestion of vegetable waste was investigated in mesophilic condition with three different organic loading rates (OLR) of 1.4, 2 and 2.75 kgVS/(m<sup>3</sup>.d) for constant retention time of 25 days. Retention time of 25 days was maintained by feeding 2.4 L of substrate and removing 2.4 L of effluent daily. Steady-state condition was identified when the COD value of the effluent and daily biogas production was measured to be the same for two or three consecutive days. Table 1 shows the characteristics of each feeding rate.

### 2.4 Analytical methods

Biogas production, Methane content in biogas and process parameters such as pH, TS, VS, alkalinity and ammonium nitrogen were followed on daily basis. Methane content in biogas was measured by gas chromatograph. TS, VS, alkalinity and PH were determined according to Standard Methods (APHA, 1998).

*Table 1: Characteristics of each feeding rate*

	Total solids (%)	Volatile solids (%)	Organic loading rate (kg VS/m <sup>3</sup> .d)	Wet waste (kg/d)	Inlet COD (mg/l)
Loading 1	8	97	1.4	1	2150
Loading 2	8.6	97	2	1.5	3300
Loading 3	8.5	97	2.75	2	4100

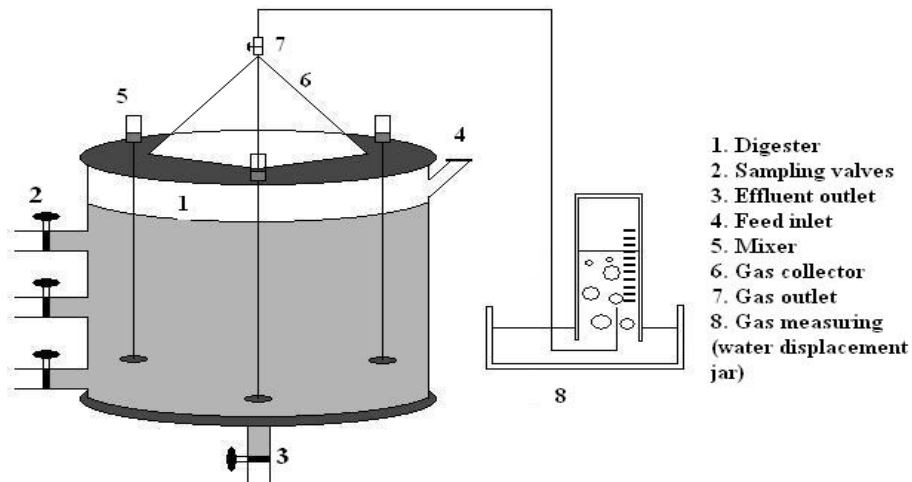


Figure 1: The experimental set-up

### 3. Results and Discussion

#### 3.1 Biogas production and characterization

One of the main objectives of this research was to determine the performance of the anaerobic digestion process when operated at different loading rates. For this reason, it was highly important to evaluate process performance in term of biogas composition and production to various loading rates. Production and composition of biogas during anaerobic process at different organic loading rates are shown in Fig. 2.

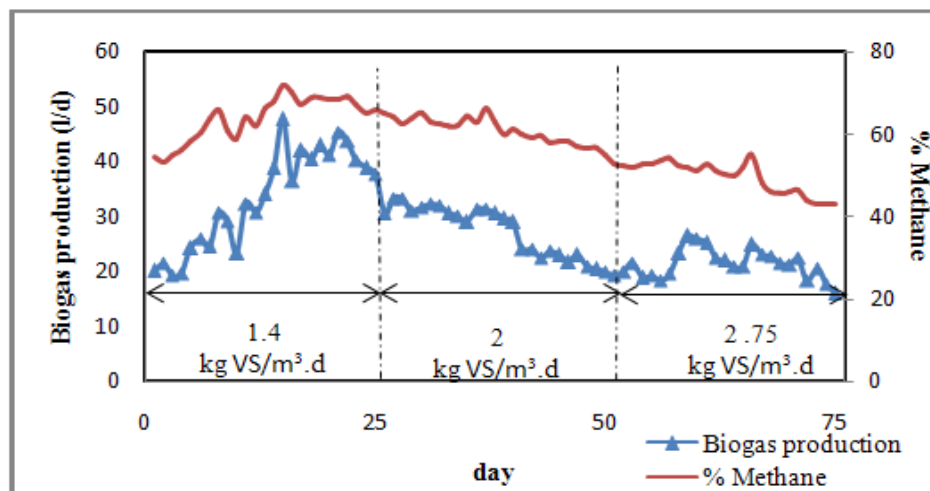


Figure 2: The amount of biogas production and composition for various loading rates

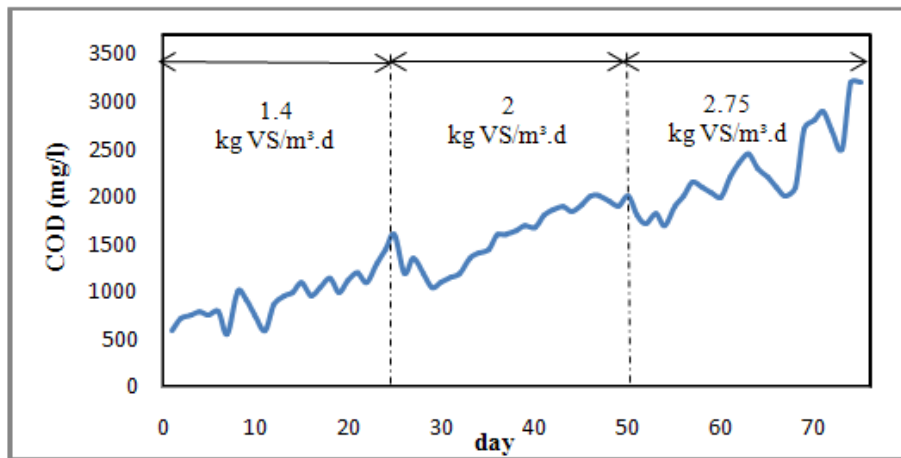


Figure 3: Values of COD for various loading rates

The biogas production at steady-state condition was found to be 33.3, 27.6 and 21.3 l/d in run 1, 2 and 3, respectively. Further increase of the organic feeding rate as 2kgVS/(m<sup>3</sup>.d) results in decreased biogas production rates. The reactor showed stable performance with highest methane (64%) during loading rate of 1.4 kg VS/(m<sup>3</sup>.d). Methane concentration in biogas was observed around 60% in run 2 whereas it was found less than 49.7% in run 3. The pH of effluent leachate from the digester remained steady state to the range of 7.75 - 8.0 during the run 1 (1.4 kg VS/m<sup>3</sup>.d) which shows that the system was well buffered. When the loading rate was increased to 2.75 kgVS/(m<sup>3</sup>.d), the pH value dropped from 7.75 and reached to lower value of 6.8. The methane content in the biogas dropped and the system showed sign of overloading. It was found that higher organic loading rates gave lower methane composition. Since the pH controlled by the volatile organic acids concentration, the alkalinity showed similar trends. This was result by immediately stopping the feeding and adding alkaline solution. But the condition could not be recovered during run 3. Figure 3 presents the variation of COD concentrations in leachate. In loading rate of 1.4 kg VS/(m<sup>3</sup>.d), COD concentrations were found significantly decreased after the completion of the retention time. But COD in leachate were found at the higher concentrations in run 2 and 3 during the digestion. This can be explained that there was higher hydrolysis but less methanogenesis because hydrolytic bacteria are more robust to environmental condition.

### 3.2 Process efficiency

For the purpose of evaluating the effect of loading rate on the performance of this system, VS reduction, and biogas yield were taken into account as the indicators to assess the reactor performance and efficiency of each loading rate. Volatile solid reduction was taken into account as well to evaluate the reactor performance and stability of the digestate. VS degradation value of 88 % was achieved when operating loading rate 1.4 kg VS/(m<sup>3</sup>.d). While loading rate increased to 2 and 2.75 kgVS/(m<sup>3</sup>.d), VS removal was decreased to 82% and 78% respectively as illustrated in Fig.4.

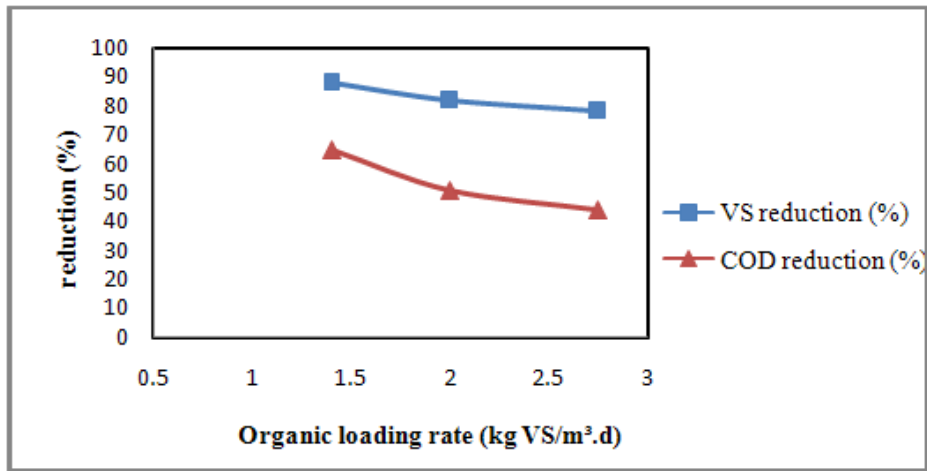


Figure 4: VS and COD degradation for various loading rates

Comparably, this VS reduction was higher with result found by Castillo et al. (2006) who reported that VS reduction of 77.1% was obtained with the digestion time of 25 days. As the organic loading rate was increased, the COD degradation decreased. In run 1, the reactor stabilized and the COD of the effluent was further reduced to 65%, which corresponds to high purification efficiency of COD removal.

To further the investigation, biogas yield for various loading rates is presented in Figure 5. The highest yield observed was 0.4 m<sup>3</sup>/kg VS in run 1 (1.4 kg VS/m<sup>3</sup>.d). As the loading rate was increased, a gradual decrease in the biogas production (0.22 and 0.12 m<sup>3</sup>/kg VS in run 2 and 3 respectively) was observed. The overloading was marked by the fall in pH and gas yield and increase of carbon dioxide content in the biogas.

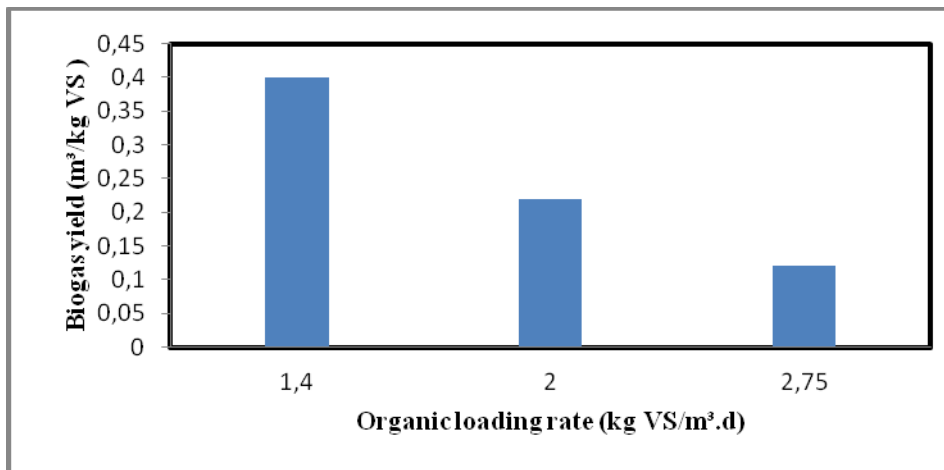


Figure 5: Biogas yield for various loading rates

In this study, the best results were obtained with an organic loading rate of  $1.4\text{kgVS}/(\text{m}^3\cdot\text{d})$ . It should be cautioned here that the optimum loading rate of  $1.4\text{kgVS}/(\text{m}^3\cdot\text{d})$  observed here is not universal as the optimal rate depends upon the reactor configuration.

#### **4. Conclusion**

The single-phase, complete-mix reactor is found to be technically feasible for vegetable wastes disposal. Considering the characteristics of the high-moisture solid waste, anaerobic digestion represents a feasible and effective method to convert the waste to biogas fuel. The reactor showed stable performance with highest methane (64%) with VS reduction of around 88% during loading rate of  $1.4\text{ kg VS}/(\text{m}^3\cdot\text{d})$ . Based on data from this study, OLR of  $1.4\text{ kg VS}/(\text{m}^3\cdot\text{d})$  is suggested as design criteria with biogas production rate of  $0.4\text{ m}^3\text{biogas}/\text{kg VS input}$ . Successful implementation of anaerobic digestion as the method of waste treatment leads to the regional utilization of renewable energy resources, reducing energy requirements and costs.

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