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Effect of pH on Biogas Production through Anaerobic Digestion of Food Waste

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ABSTRACT

In the present study, the effect of pH (6, 7 and 8) on the biogas production was investigated experimentally in laboratory scale anaerobic batch bioreactors. The hydraulic retention time taken for digestion is 30 days. The volumetric yield of biogas was noted at regular intervals using water displacement method. The experimental results show that the pH 7 produced higher biogas yield compared to pH 6 and 8. Modified Gompertz model was evaluated for biogas yield and the corresponding kinetic parameters were estimated.

Keywords - Anaerobic Digestion, Biogas, pH, Food waste.

1. INTRODUCTION

The growing demand for energy, depletion of fossil fuel resources, hikes in crude oil prices, and the increasing concern for environmental issues have challenged researchers to develop new technological processes to obtain clean and sustainable energy through the utilization of renewable energy sources [1-3]. In this regard, biogas produced from organic wastes and energy crops can play a pivotal role in meeting world energy demand [4, 5]. Biogas from food wastes, residues and marine biomass are worth considering for energy utilization [6].

Anaerobic digestion is widely as a treatment option for the disposal of municipal solid waste on a par with the composting technologies. It mainly combines with the energy recovery benefits, greenhouse gas mitigation and produces stable end products, which can be further upgraded as compost for land use applications [7, 8]. In anaerobic digestion, various organic materials are digested by microorganisms in the absence of air/oxygen and produce energy rich biogas, which can be used for electricity generation, thermal power and automobile applications [9, 10].

To maximize the rate of biogas production, it is essential to optimize the process parameters involved in the digestion process. Many researchers investigated the effects of process parameters involved in the biogas production and reported their findings. Raheman et al [11] studied the influence of solid concentration using jatropha deoiled cake in an anaerobic biodigester and reported that solid concentration of 20% yielded maximum biogas compared to others. Sivakumar et al. [12] investigated the effect of pH using spoiled milk as substrate and reported that the substrate with 7 pH resulted better biogas yield. Kafle et al [13] investigated the effect of co-digestion of Kimchi factory waste silage and swine manure under mesophilic temperature condition. The results suggested that Kimchi factory waste could be effectively treated by making silage, and the silage could be used as a potential co-substrate to enhance biogas production from swine manure digester. Deepanraj et al. [14] studied the effect of temperature on biogas production using food waste in a lab scale batch reactor and found that the operating temperature of 50°C achieved maximum biogas yield.

The objective of the present investigation is to study the effect of pH on biogas production through anaerobic digestion of food waste.

2. MATERIALS AND METHODS

2.1 Feed Stock

The food waste used in this study was collected from the canteen of Surya Group of Institutions, Vikiravandi India. Table 1 shows the mean chemical composition of food waste used in this present study. The collected food waste was crushed and mixed with water to get the solid concentration of 10% of total solids, which is already optimized in the previous study [15]. Anaerobic microbial sludge collected from an anaerobic digester operated with cattle manure was used as inoculum for the reactors.

Table 1: Elemental composition and COD of raw food waste

Characteristics	Values
Carbon (%)	46.19
Hydrogen (%)	12.05
Oxygen (%)	39.58
Nitrogen (%)	1.94
Sulfur (ppm)	2357
Total COD (g/L)	314
Soluble COD (g/L)	152
C/N ratio	23.72

2.2. Experimental setup

Experiments were carried out in laboratory-scale batch reactors made up of glass. The volume of each reactor is 1,000 mL with a working volume of 750 mL. The schematic view of experimental setup is shown in Fig. 1. All the reactors were purged with nitrogen before start-up in order to create anaerobic condition. Continuous mixing was performed using magnetic stirrer. Thermophilic temperature (50°C) was maintained throughout the experiments for the hydraulic retention of 30 days. Temperature and pH probes were installed in the reactors for daily monitoring.

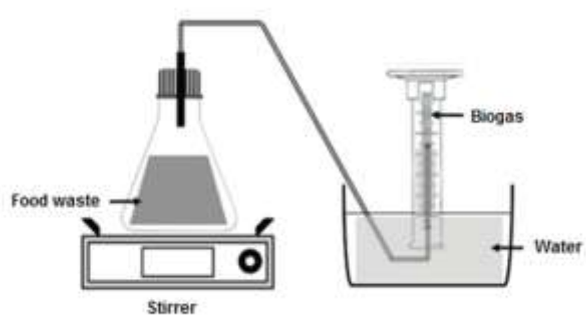

Fig 1. Schematic view of experimental setup

4. Kinetic study

Various kinetic models are available to give a detailed description of bioconversion mechanism. In this study, we used modified Gompertz model to evaluate the biogas production potential of the substrate, maximum biogas production rate and the lag phase of the biochemical reaction [16, 17].

$$C = Bexp\left\{-\exp\left[\frac{R_b e}{B}(\lambda - t) + 1\right]\right\} \quad (1)$$

where C is the cumulative biogas production (mL); B is the biogas production potential (mL); R_b the maximum methane production rate (mL/d); λ is the duration of lag phase (d) and t is the duration of the assay at which cumulative biogas production C is calculated. The parameters B, R_b and λ were determined by applying a least squares fit of the above equation using MATLAB software.

3. RESULTS AND DISCUSSION

The effect of three different pH 5, 6 and 7 on anaerobic digestion of food waste was carried out in the laboratory scale bio-digesters of 1000 mL capacity. The characteristics of food waste before and after the digestion process were given in Table 2 and 3 respectively. Daily and cumulative biogas production with respect to retention time was determined which is shown in Fig 2 and 3 respectively. The cumulative biogas produced by the reactors with pH 6, 7 and 8 are 2948, 3617 and 3294 ml respectively. Out of three different pH, substrate with pH 7 yielded higher gas production, followed by 8 and 6 respectively. Similar trend were obtained for Deepanraj et al. [18] and Wu et al. [19], who experimented the pH effect on anaerobic digestion.

Table 2: Characteristics of food waste before digestion

Parameters	Values
TS (g/L)	100
VS (g/L)	89.81
FS (g/L)	10.19
COD (g/L)	76.79

Table 3: Characteristics of food waste after digestion

Parameters	pH 6	pH 7	pH 8
TS (g/L)	49.80	43.30	46.60
VS (g/L)	40.51	35.84	37.82
FS (g/L)	9.29	7.46	8.78
COD (g/L)	42.91	37.94	39.78

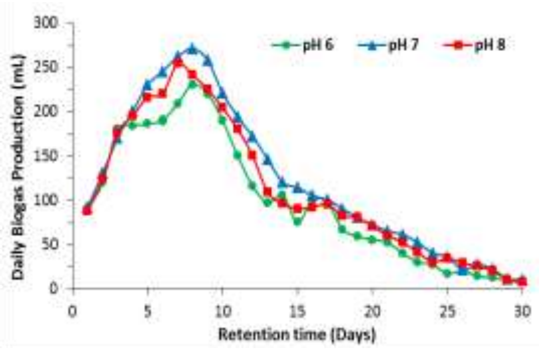

Fig. 2. Daily biogas production.

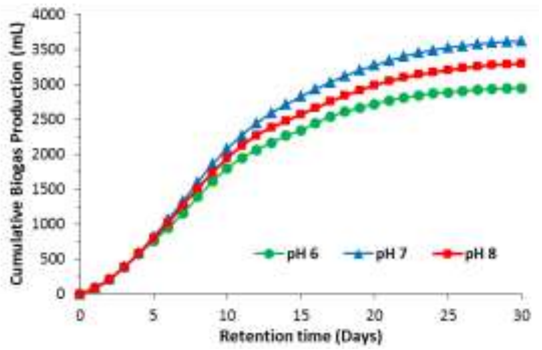

Fig. 3. Cumulative biogas production.

The total solid (TS), volatile solid (VS) and chemical oxygen demand (COD) removal efficiencies were shown in Fig. 4. In all the cases, reactor with pH 7 achieved maximum degradation and pH 6 achieved minimum degradation. The TS removal efficiency of the reactors with substrate pH 6, 7 and 8 are 50.2, 56.7 and 53.4%, respectively. The VS removal efficiency of the reactors with pH 6, 7 and 8 are 54.9, 60.1 and 57.9% respectively. Similarly, the COD removal efficiency of the reactors with substrate pH 6, 7 and 8 are 44.12, 50.6 and 48.2%, respectively.

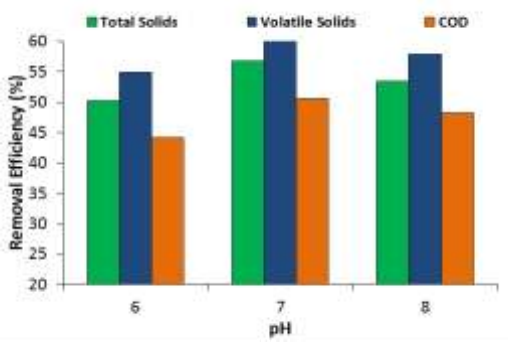

Fig. 4. TS, VS and COD removal efficiencies.

Based on the modified Gompertz model (Eq. (1)), the maximum values of biogas production that could achieve during the stabilization of anaerobic digestion process were determined. The kinetic constants were calculated for 30 days of digestion time because the time needed for 90% biogas production fell within this range. The comparison of experimental and predicted cumulative biogas production based on the above results is shown in Fig. 5. Biogas yield potential of the substrate (B) with pH 6, 7 and 8 are found to be 2961.4, 3630.1 and 3295.2 mL respectively. This shows that the reactor with pH 7 achieved maximum biogas yield potential followed by 8 and 6. Calculated lag time was found to be in between 1.4 and 2.7 days. The coefficienct of determination (R^2) for the reactors with pH 6, 7 and 8 are 0.9584, 0.9970 and 0.9915 respectively. This shows that the results taken from the model were best fitted with the experimental study.

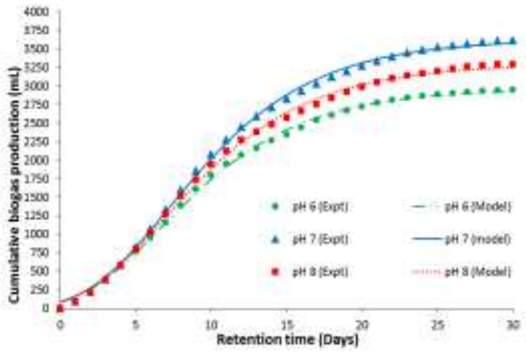

Fig. 5. Comparison of experimental and predicted results

Table 4: Estimated kinetic parameters

Parameter	6	7	8
C-Experimental (mL)	2948	3617	3294
C-Model (mL)	2926.5	3578.3	3250.9
B (mL)	2961.4	3630.1	3295.2
R_b (mL/day)	207.8	248.3	225.9
λ (days)	1.4	1.7	1.5
R^2	0.9584	0.9870	0.9975
RMSE (%)	36.29	43.60	46.25

6. CONCLUSION

The effect of pH on biogas production was evaluated experimentally using food waste as substrate. The food waste with pH 6, 7 and 8 resulted in a cumulative biogas production of 2948, 3617 and 3294 mL respectively. The experimental results were fitted with modified Gomperz model to determine the kinetic parameters.

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