

ASI

Carbon – Science and Technology

ISSN 0974 – 0546

http://www.applied-science-innovations.com

ARTICLE

Received : 24/12/2013, Accepted :30/12/2013

Energy from Biomass – Comparison of biogas production at ambient temperature and at mesophilic temperature in semicontinuous anaerobic digester using vegetable market wastes

Dhanalakshmi Sridevi V [A] and Srinivasan S V [B]

(A) Department of Chemistry, GKM College of engineering and Technology, Chennai - 600063, India.
(B) Environmental Technology Division, Central Leather Research Institute, Adyar, Chennai – 600020, India.

Studies are conducted in semicontinuous anaerobic reactors of 2 L Capacity with effective volume of 1.5 L. Experiments were carried out in the mesophilic temperature range maintained at 35°C in a thermostat, and parallel experiments were performed at ambient temperature on biogas production from the month of Februray to August. The reactors were operated with an organic loading rate of 0.5 gVS/L/d with 25 days HRT. The feed stock used for the study was vegetable market waste obtained from Koyambedu vegetable market. The specific biogas production was found to be 0.530 L gVS_{add}^{-1} for the reactor operated at mesophilic temperature and in the range of 0.431 to 0.732 L gVS_{add}^{-1} for the reactor operated in the ambient temperature condition from the month of February to August. The daily biogas production was found to be similar (approximately 350 mL/d) when reactors were operated at mesophilic and ambient temperature except for the period of May and June wherein higher amount of daily biogas production (472 and 529 mL/d) was observed in the reactor operated at ambient temperature. The ratio of total VFA and alkalinity and propionic acid to acetic acid (PA/AA) was found to be in the range of 0.25 – 0.4 and 0.34 - 1.38 during the operation of the reactor for the entire period, which was within the range reported for digester stability.

Keywords: Anaerobic digestion; vegetable market wastes; specific biogas; propionic acid; acetic acid

---

1. Introduction: Dawn of industrial era results in urbanization, cities are main centers of economic growth, trade, education innovations, and employment, which in turn increases the consumption of resources and generation of wastes. Therefore, the burning problem that the world faces is management of large quantity of solid wastes produced from all sources, such as industrial, mining, domestic, and agricultural activities and the energy requirements due to the rapid growth of population and uncontrolled and unmonitored urbanization. Vegetable wastes are produced in a large scale in markets in cities. Vegetable markets generate tons of vegetable wastes every day because of its putrescible nature. Chennai city in Tamil Nadu, India, with a population of approximately 4.6 million, generates 150 tons of wastes per day at Koyambedu vegetable market alone [1], one of Asia's biggest markets for vegetables, fruits, and flowers.. Currently, these wastes, which are a good substrate for anaerobic digestion process because of high biodegradability, are dumped in open landfill. Vegetable wastes are a kind of biomass where solar energy is stored in the form of chemical

energy as organic fraction like carbohydrates, proteins and fat by the process of photosynthesis. This stored energy can be converted to other form of energy as per thermodynamic law which states that "Energy can be converted from one form to another form". Therefore, the chemical energy stored in vegetable wastes can be converted into any other form of energy instead of dumping and creating pollution problems. The energy from organic fraction can be recovered by two methods (i) by thermo chemical conversion method and (ii) biochemical conversion method. Among all the methods used for biochemical conversion methods, anaerobic digestion is a potential environment friendly technique to produce energy in the form of biogas **[2, 3]**, and residue, which can be used as soil conditioner **[4 – 6]**. Functioning of the anaerobic digester in continuous mode is influenced by several parameters such as organic loading rate (OLR), hydraulic retention time (HRT), temperature, and pH. To enhance the methane generation, many researchers have studied various operational parameters such as pH **[7]**, temperature **[8, 9]**, OLR **[10, 11]** and HRT **[12, 13]**. The main objective of this study is to compare the biogas production in a single-phase semi-continuous anaerobic reactor at ambient temperature and at mesophilic temperature (35°C maintained in a thermostat) to know the effect of temperature in biogas production.

2. Experimentation : The studies were performed in laboratory-scale reactors each of 2 L capacity (in triplicate) in semi-continuous mode. The effective volume of the reactors was maintained at 1.5 L. The reactor was provided with suitable arrangements for feeding, gas collection, and draining of digested slurry. The reactor was operated by draw and fill method. Experiments were performed in the mesophilic temperature range maintained at 35°C in a thermostat, and parallel experiments were performed at ambient temperature on biogas production. The schematic diagram of the experimental setup is shown in Figure (1). The experimental setup in the laboratory is shown in Figure (2). Each reactor was initially inoculated with 750 mL of anaerobic seed sludge, obtained from an active mesophilic digester of biomethanation plant at Koyambedu, Chennai, India, working with vegetable waste. The feedstock selected for the experiment was ground mixture of vegetable market waste, stored at 4°C until used. The feed was prepared daily by diluting the mixture with distilled water to the desired OLR (0.5 gVS/L/d). The digesters were fed every day, with 60 mL of feed by replacing equivalent volume of digester content to maintain a HRT of 25 days. The reactor was operated from the month of February to August to study the effect of ambient temperature.

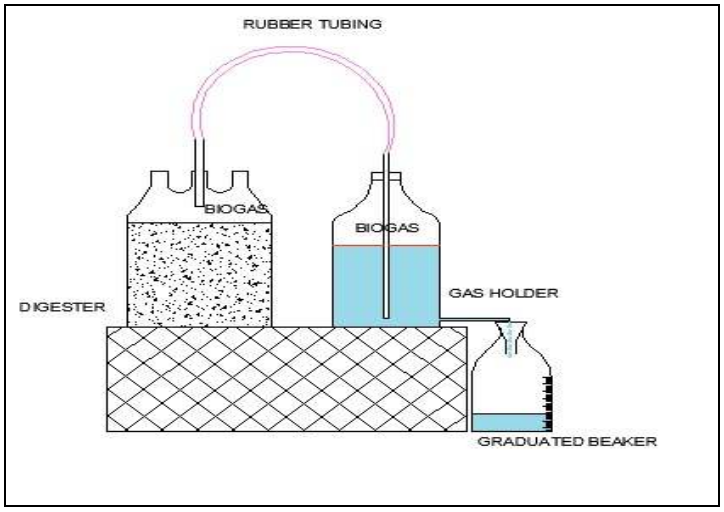

Figure (1) : Schematic representation of semi-continuous reactor.

Figure (2) : The reactor set up in thermostat.

2.1 Analytical methods: Total solids (TS), volatile Solids (VS) and alkalinity were estimated according to the procedures recommended in standard methods (APHA –AWWA 1992). Volatile fatty acids and percentage of methane were determined using a gas chromatograph as already reported **[14]**. The pH of samples was measured by using digital pH meter.

3. Results and Discussion:

3.1 Biogas production at mesophilic temperature: Daily biogas production and pH for the OLR (0.5gVS/L/d) studied at mesophilic temperature is shown in Figure (3) and the average daily biogas production was 379± 40, specific biogas production was 0.530 L/gVS_{add} and the methane production was 0.344 LCH_4/gVS_{add}. Average alkalinity was found to be in the range of 1,096–1,184 mg/L as CaCO3 equivalent during the study. The feed prepared with vegetable wastes had an average pH range of 5.8–6.5. The pH of reactor was monitored during the operation and found to be in the range of 7.4–8.1. The pH values observed were within the optimum pH range (6.8–7.4) reported for the growth of methanogens in the anaerobic digestion process expect for 15 days HRT **[15]**. Methane content in the gas was considered as 65 %, and methane production was estimated as 0.344 LCH4/gVSadd. Similar results were reported by other researchers for similar substrates **[16 – 18]**.

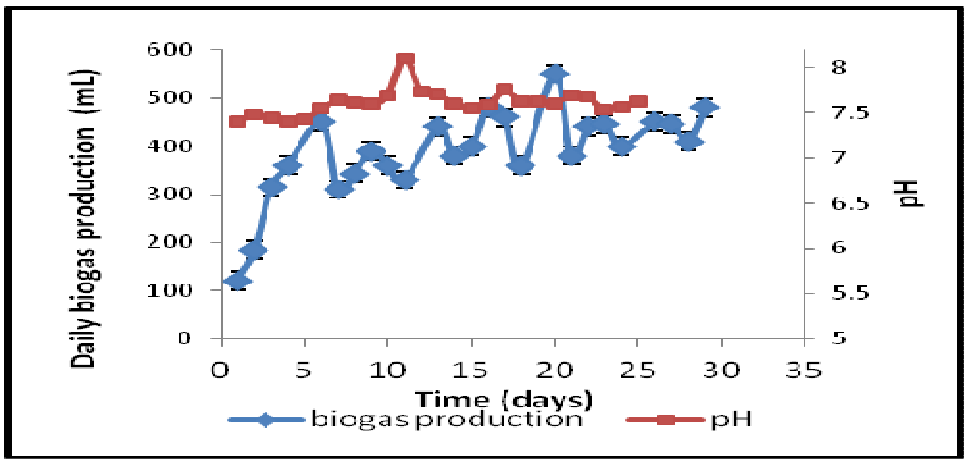

Figure (3) : Daily biogas production and the pH for the OLR of 0.5 gVS/L/d at mesophilic temperature.

VFA profile of the reactor was monitored and is shown in Figure (4). VFA profile shows the presence of acetic acid and propionic acid predominantly till 6 days and decreased to a low level at later stage. The biogas production started increasing after 6 days and reached maximum when the concentration of all acids were less than 500 mg/L. Concentration of acetic acid and ratio of propionic acid to acetic acid (PA/AA) has been reported as an indicator for digester activity, and the value of ratio of PA/AA <1.4 is reported for better stability of the reactor [19]. In this study, the ratio of PA/AA observed for all the reactors operated with OLR of 0.25–1.5 gVS/L/d was in the range of 0.06–1.31 indicating the stability of reactors.

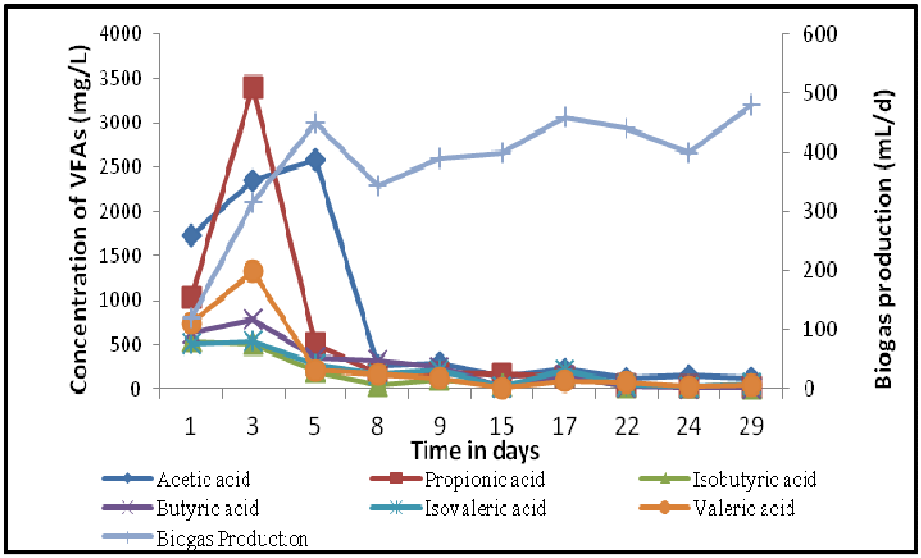

Figure (4) : Comparison of Biogas production and concentration of volatile fatty acids for an OLR of 0.5 gVS/L/d.

3.2 Biogas production at ambient temperature:

The pH, average daily biogas production, specific biogas and methane production, observed for an OLR of 0.5 gVS/L/d at ambient temperature during the period from February to august are shown in Table (1). The daily biogas production for the entire study period at ambient temperature is shown in Figure (5). For the study period, feed prepared with vegetable wastes had an average pH of 5.8–6.5. pH of the reactor was monitored during the operation of the reactor and was found to be in the range of 6.85–7.5, which were within the optimum range. From the results, it is observed that specific biogas production for the month of May and June were increased to 0.678 and 0.809 L/gVS_{add} respectively. Similarly specific methane production were also increased to 0.406 and 0.485 LCH_4/gVS_{add}, when the monthly average atmospheric temperature was reported to be 37.7 ºC and 37.22 ºC [20] for the month of May and June respectively. The total VFA and alkalinity of the digested slurry were determined, and VFA/alkalinity ratio was found to be in the range of 0.25–0.4, within the range reported for reactor stability [21]. pH and VFA/alkalinity ratio values clearly indicate that the reactor was completely stable and steady throughout the period.

Table (1) : pH, average daily biogas, specific biogas and methane production at ambient temperature for the months from February to August and for the reactor.

Period of Study	pH range	Average biogas production daily (mL)	Specific biogas production (L/gVS_{add})	Specific methane production (LCH_4/gVS_{add})
February	6.87 – 7.52	334± 30	0.510	0.306
March	6.85 – 7.2	331± 15	0.508	0.304
April	6.82 – 7.1	334± 20	0.456	0.273
May	6.83 – 7.5	472± 10	0.678	0.406
June	6.9 – 7.4	529± 25	0.809	0.485
July	6.8 – 7.3	356± 15	0.576	0.345
August	6.8 – 7.0	129± 10	0.535	0.321

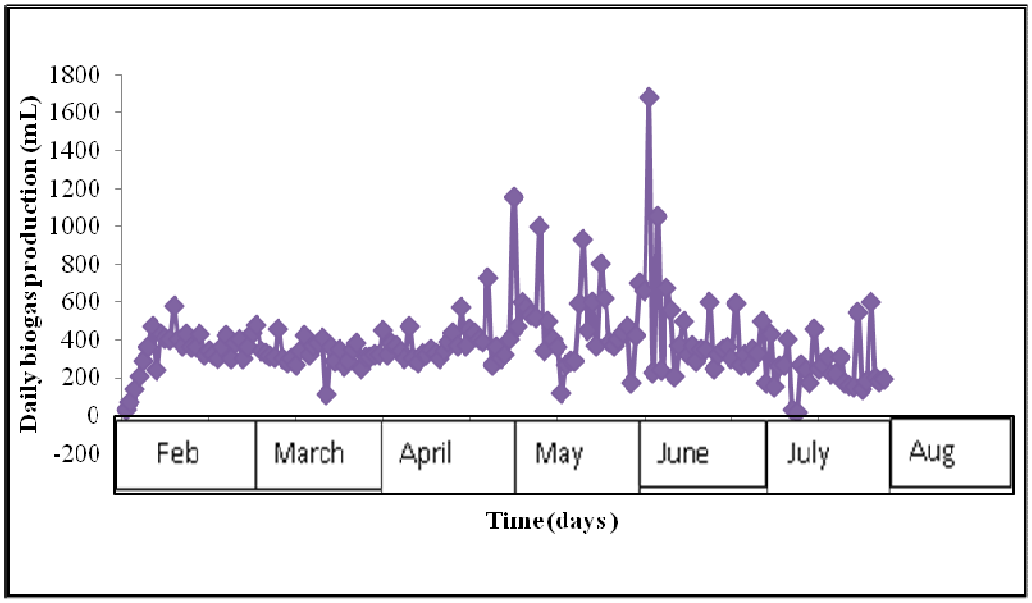

Figure (5) : Daily biogas productions for the period from February to August for an OLR of 0.5gVS/L/d at ambient temperature.

VFA profile of the reactor was monitored during the intermediate days of operation and is shown in Figure (6). VFA profile shows that acetic acid is predominant on all specified days followed by propionic acid, valeric acid, and butyric acid for the OLR 0.5 gVS/L/d studied. The ratio of PA/AA was found to be in the range of 0.34 and1.38 during the operation of the reactor for the entire period, which was below the reported value for digester stability 1.4 [19]. The predominant presence of acetic acid in all the three reactors and the ratio of propionic acid to acetic acid confirm that the acid-

producing bacteria were active and conditions that prevailed in the reactor seemed to be favorable for methanogenesis

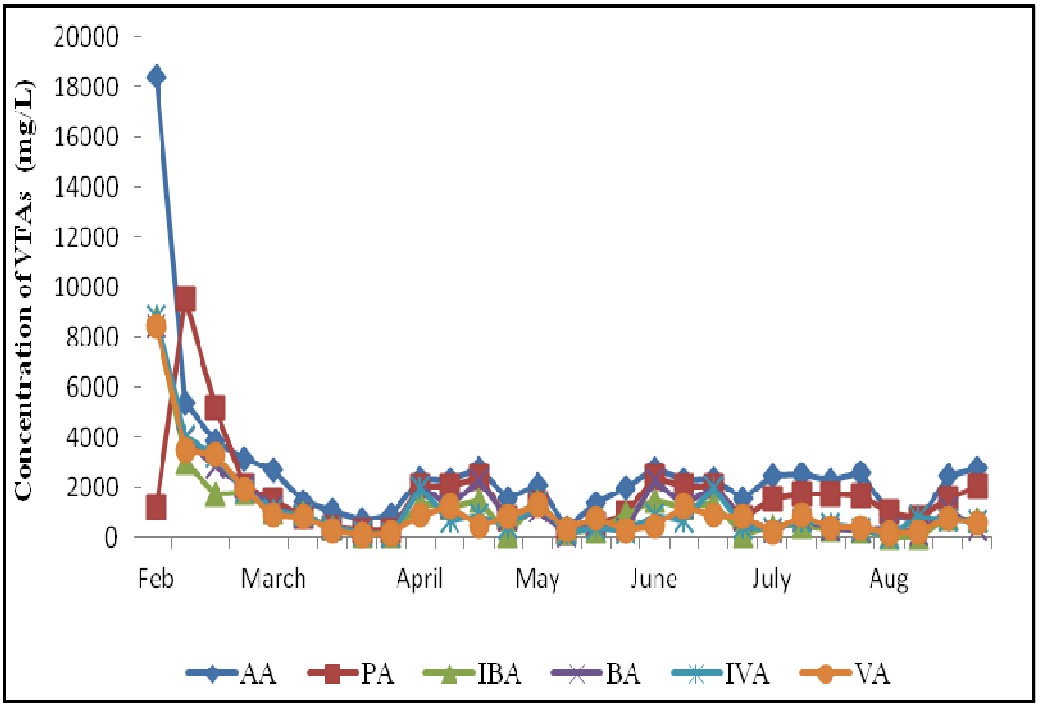

Figure (6) : VFA profile for the OLR 0.5 gVS/l/d.

5. Conclusions: On the basis of the current study, it was concluded from anaerobic digestion of vegetable waste operated in a single-phase semi-continuous laboratory-scale reactor in ambient temperature and mesophilic temperature that the daily biogas production was found to be similar when reactors were operated at mesophilic and ambient temperature with an OLR of 0.5gVS/L/d except for the period of May and June wherein higher amount of daily biogas production was observed in the reactor operated at ambient temperature. For maintaining the mesophilic conditions, we need to provide power, which may result in increased cost.

6. References:

[1] http://en.wikipedia.org/wiki/Koyambedu_Wholesale_Market_Complex.
[2] H. Bouallagui, R. BenCheikh, L. Marouani and M. Hamdi, 'Mesophilic biogas production from fruit and vegetable waste in tubular digester'. *Bioresour Technol*, 86 (2003) 85 - 90.
[3] J. Mata. Alvarez, F. Cecchi, P. llabres and P.Pavan, 'Anerobic digestion of the Barcelona central food market organic wastes: plant design and feasibility study', *Bioresour. Technol.* 42 (1992) 33 - 42.
[4] J. Mata. Alvarez, F. Cecchi, P. llabres and P.Pavan, 'Anerobic digestion of the Barcelona central food market organic wastes: plant design and feasibility study', *Bioresour. Technol.* 39 (1992) 39 - 48.

[5] D. Verrier, F. Ray and M. Florentz, 'Two – stage anaerobic digestion of solid vegetable wastes: bench scale studies', Proceedings of the 3rd International symposium of Anaerobic Digestion, Boston, USA, pp. (1983) 17 – 19.
[6] B. K. Ahring, Z. Mladenovska, R. Ianpour and P. Westermann, 'State of the art and future perspectives of thermophilic anaerobic digestion', *Water Sci. Technol.* 45 (2002) 298 - 308.
[7] C. Liu, X. Yuan, G. Zeng, W. Li and J. Li, 'Prediction of methane yield at optimum pH for anaerobic digestion of organic fraction of municicpal solid waste', *Bioresource. Tecchnology*, 99/4 (2008) 882 - 888.
[8] K. Komemoto, Y. G. Lim, N. Naga, Y. Onue, C. Niwa and T. Toda,'Effect of temperature on VFA's and biogas production in anaerobic solubilization of food waste', *Waste Management* 29/12 (2009) 2950 - 2955.
[9] M. A. Rahman and P. Elefsiniotis, 'The effect of upper mesophilic temperature on feed to seed ratio on batch anaerobic digestion systems', *Journal of Environmental Science and Health* A45/9 (2010) 1126 - 1133.
[10] Barbara Rincon, Lissette Travieso, Enrique Sanchez, Maria de los Angeles Martin, Antonio Martin, Francisco Raposo and Rafael Borja, 'The effect of organic loading rate on the anaerobic digestion of two-phase olive mill solid residue derived from fruits of with low ripening index', *Journal of Chemical Technology and Biotechnology* 82 (2007) 259 – 266.
[11] G. D. Najafpour, A. A. L. Zinatizadeh, A. A. L. Mohamed, 'High-rate anaerobic digestion of palm oil mill effluent in an upflow anaerobic sludge-fixed film bioreactor', *Process Biochemistry* 4/2 (2006) 370 - 379.
[12] L. Feng, H. Wang, Y. Chen, 'Effect of solids retention time and temperature on waste activatedsludge hydrolysis and short-chain fatty acids acuumulation under alkaline conditions in continuous-flow reactors', *Bioresource Technology* 100/1 (2009) 44 - 49.
[13] P. Fongsatitkul, P. Elefsiniotis and D. G. Wareham, 'Effect of mixture ratio, solids concentration and HRT on the anaerobic digestion of the organic fraction of municipal solid waste', *Waste Management and Research* 28/9 (2010) 811 - 817.
[14] Dhanalakshmi Sridevi V., S. V. Srinivasan, R. Kayalvizhi and R. Bhuvaneshwari, 'Studies on conversion of carbohydrate content in the mixture of vegetable wastes into biogas in a single stage anaerobic reactor', Res. J. Chem. Sci. 2/6 (2012) 66 - 71.
[15] V. K. Sharma, C. Testa, G. Cornacchia, G. Lastella, and R. Farina, 'Anaerobic digestion of semi-solid organic waste available from ortho fruit market: Preliminary experimental results', *Energy Conservation and Management*, 40 (1999) 287 – 304.
[16] B. Nirmala, S. Deepak and Sunil Khanna, 'Biomethanation of banana peel and pineapple waste', *Bioresource Technology* 58 (1996) 73 - 76.
[17] A. G. Lane, 'Laboratory scale anaerobic digestion of fruit and vegetable solid wastes', *Biomass* 5 (1984) 245 - 259.
[18] S. K. Sharma, I. M. Mishra, M. P. Sharma and J. S. Saini, 'Effect of particle size on biogas generation from biomass residues', *Biomass* 17 (1988) 251 - 263.
[19] D. T. Hill, S. A. Cobb and J. P. Bolte, 'Using Volatile Fatty Acid Relationships to Predict Anaerobic Digester Failure', *Trans. ASAE* 30 (1987) 496 – 501.
[20] http://www.meoweather.com/history/India/na/13.083333/80.283333/Chennai.html
[21] F. J. Callaghan, D. A. J. Wase, K. Thayanithy and C. F. Forster, 'Continuous Co-digestion of Cattle Slurry with Fruit and Vegetable Wastes and Chicken Manure', *Biomass and Bioenergy* 27 (2002) 71 – 77.