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Studies on Conversion of Carbohydrate content in the Mixture of Vegetable Wastes into Biogas in a Single Stage Anaerobic Reactor

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Abstract

In the present study mixture of vegetable wastes were an-aerobically digested in a single stage mesophilic reactor. Vegetable wastes having near similar pH and moisture content have been chosen (carrot, beans and brinjal having pH 5.4, 5.8 and 5.7 respectively and moisture content 89.8%, 90.29% and 89.4% respectively) so that total solids content do not vary significantly in the feed composition for the study. These wastes contain predominantly carbohydrates and less protein and fat. The reactors were operated at two different organic loading rates (OLR) 0.25 and 0.5gVS/l.d, with the Hydraulic Retention Time (HRT) of 25days. The performance of the reactors was evaluated by estimating destruction of total and volatile Solids and by monitoring daily gas production. Volatile fatty acid (VFA) profile was determined for each organic load during the operation. The biogas yield was, 0.383 and 0.522 l/gTS_{added} and 0.423 and 0.576 l/gVS_{added} for the two OLR respectively. The methane content in the gas was around 63% and methane yield was 0.226 and 0.362 l CH_4 / gVS_{added} for the selected vegetables for the two OLR respectively. The objective of this paper was to study the effective conversion of carbohydrate content in the selected mixture of vegetable wastes in a single stage anaerobic reactor for biogas production.

Keywords: Anaerobic digestion, fruit and vegetable wastes, biogas, batch reactor, VFA profile

Introduction

Fruit and vegetable wastes are produced in large quantities in markets and constitute a source of nuisance in municipal landfills due to their high biodegradability. According to Indian agricultural research data book, the losses in fruits and vegetables are to the tune of 30%. Fruit and vegetables are a type of biomass where energy is stored in the form of carbohydrates, proteins and fat which may be converted into any other form of energy through thermo chemical conversion or biochemical conversion process. Biological conversion of biomass to methane has received increasing attention in recent years[1]and is suitable for wastes containing moisture content above 50% than thermo conversion process[2].

Anaerobic Digestion is a type of biochemical conversion process and is the most environmentally friendly and promising technique which will result in the production energy in the form of biogas and reduce the organic content of waste[3-5]. Vegetable wastes, due to high biodegradability nature[6, 7], high organic content and high moisture content (75 – 90%), are a good substrate for the production of biogas through anaerobic digestion process. Several studies have been reported on the bioconversion of biomass by different researchers. For example, Bouallagui et al[2] tested for the conversion of fruit and vegetable waste (FVW) into biogas in a semi-continuously mixed mesophilic tubular anaerobic digester. Ojolo et al[8] examined the biogas production potential of vegetable component of municipal solid waste in a batch fed 200dm^3 capacity anaerobic digester. Prema Viswanath et al[9] studied the effect of OLR and HRT in a semi continuous CSTR of 60-liter capacity reactor. Knol et al[10] studied different fruit and vegetable wastes in a continuously stirred tank reactor (CSTR). Patil et al[11] studied the anaerobic co digestion of water hyacinth for biogas production.

The process of digestion and production of biogas depends on the composition and the fermentation products of the vegetable wastes. Carbohydrates constitute a large fraction of vegetable feedstock. Most of the carbohydrate is in the form of insoluble polysaccharides with sometimes soluble polysaccharides and sugars. Breakdown of carbohydrates is the primary energy producing reaction. Complex polysaccharides will undergo hydrolysis and fermentation in the digester while the soluble polysaccharides and sugars directly undergo fermentation. Proteins and fat undergo hydrolysis, deamination and fermentation to produce biogas. Vegetable wastes largely contain carbohydrates. Proteins and fats are present relatively in low concentrations. Keeping in view the biogas yield reported for the carbohydrates, fat and proteins, vegetable wastes, which have near similar pH, moisture content and carbohydrates, namely, carrot, beans and brinjal, were chosen as model components to study the performance of mixture of wastes in the anaerobic digestion process[12]. A major limitation of anaerobic digestion of vegetable wastes is the rapid acidification due to the lower pH of wastes and the larger production of volatile fatty acids (VFA) which reduce the methanogenic activity of the reactor[13].

The main objective of this research is to study the process of conversion of carbohydrates present in the vegetable wastes into biogas in a single stage mesophilic continuous anaerobic reactor.

Material and Methods

Inoculum and Feedstock: Inoculum was obtained from an active mesophilic digester of vegetable market waste biomethanation plant at Koyembedu, Chennai, India, and diluted to 1.5lit using distilled water. The inoculum was passed through 1mm sieve mesh and stored at 4^{o}C until used. The total solid content of the inoculum was 13.90% and volatile solid was 43.82%. The pH of the inoculum was 6.5. The feedstock selected for the experiment was grinded mixture of three vegetables, namely, carrot, beans and brinjal kept at 4^{o}C until used. Characteristics of the vegetable feed are shown in table.1.

Table-1
Characteristics of the vegetables

Sl. No	Component	Carrot	Beans	Brinjal
1	pH	5.4	5.8	5.7
2	Moisture Content	89.9%	90.29%	89.4%
3	Total Solids	8.91%	8.52%	8.25%
4	Volatile Solids	84.76%	85.8%	90.49%
5	Carbohydrate *	5.6	4.1	5.7
6	Fat*	0.2	0.2	0.19
7	Protein*	0.6	1.9	1.01

* Amount in gm present in 100gm

Experimental Procedure: Studies were carried out in four laboratory scale reactors of 2 lit capacities (R1, R2, and R3). The reactors were made of borosilicate glass. The effective volume of the reactors was maintained at 1.5 lit. The reactor was provided with suitable arrangements for feeding, gas collection and draining of residues. The reactor was operated by draw and fill method. Experiments were carried out in the mesophilic temperature range. Each reactor was initially inoculated with 750 ml of sludge diluted to 1.5 lit. Each reactor was charged daily with a calculated quantity of substrate equivalent to 0.25 and 0.5gVS/l.d organic loading rate (OLR) with 25 days hydraulic retention time (HRT). One reactor was kept as control. Daily biogas production was measured by water displacement method. The volume of water displaced from the bottle was equivalent to the volume of gas generated.

Analytical Methods: Analysis of samples for total solids (TS), volatile solids (VS), alkalinity, total volatile fatty acid (VFA) and pH was carried out in accordance with the procedures prescribed in IS9234 – 1979, IS10158 – 1982 and standard methods of examination of water and waste water as appropriate.

The different volatile fatty acid levels were determined by gas chromatography – capillary column EC1000, ID 0.53, Thickness. 1.2µ - Mayura analytical GC, India - equipped with a flame ionization detector and glass column. The ignition port, detector and oven temperature were maintained at 250^{o}C. Nitrogen was used as carrier gas.

Composition of methane in the biogas was measured with a gas chromatograph (Mayura Analytical, India) containing a Porapak Q of 2m length using thermal conductivity detector (TCD). Nitrogen was used as a carrier gas with a flow of 30ml/min. The oven, injector and detector temperatures were kept at 50, 100 and 100^{o}C respectively.

Results and Discussion

pH, Alkalinity and Total VFA Variation in the reactor: Optimum pH range for the for methanogens growth in the anaerobic digestion process is 6.8 to 7.4[14]. The vegetable wastes were fed with an average pH of 5.2 – 5.6 and the pH of reactor residue was, 6.9 – 7.09 and 6.87 -7.04 for the two OLR which was in the range of optimal pH. The pH profile for the two reactors was shown in figure 1and 2. The reactor stability can be estimated using VFA/alkalinity ratio. This ratio should be less than 0.4 for the reactor to be stable[15]. The VFA/alkalinity ratio is shown in figure 3 which is ranging from 0.25 to 0.4 for all the reactors during the study period. pH and VFA/alkalinity ratio values clearly indicate that the reactor was completely stable and steady throughout the HRT.

VFA Profile: VFA profile for the two organic loading rate is shown in figure 4 and 5. VFA profile shows that acetic acid is predominant on all specified days followed by propionic acid, valeric and butyric acid for the OLR 0.25 and 0.5 gVS/l.d. The ratio of propionic acid to acetic acid is 0.5 to 0.98 for both the OLR. Hill et al [16] suggested that the concentration of acetic acid and ratio of propionic acid to acetic acid can be used as an indicator for digester activity and showed that ratio of propionic acid to acetic acid greater than 1.4 indicates digester failure. 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 is active and conditions prevailing in the reactor seemed to be favourable for onset of methanogenesis.

Biogas Yield and Percentage conversion of Total Solids and Volatile Solids: The daily biogas production for the two OLR is shown in figure 6. The average biogas production was 0.150and 0.300 l/day for the OLR 0.25 and 0.5gVS/l.d respectively. The percentage conversion of TS and VS was in the range of 53 -

62% and 62 – 67% respectively for the two OLR. The biogas yield was, 0.383 and 0.522 l/gTS$_{added}$ and 0.423 and 0.576 l/gVS$_{added}$ for the two OLR respectively. The methane content in the gas was around 63% and methane yield was 0.226 and 0.362 l CH_4 / gVS$_{added}$ for the selected vegetables for the two OLR respectively. These values are comparable with the literature values[17-19]

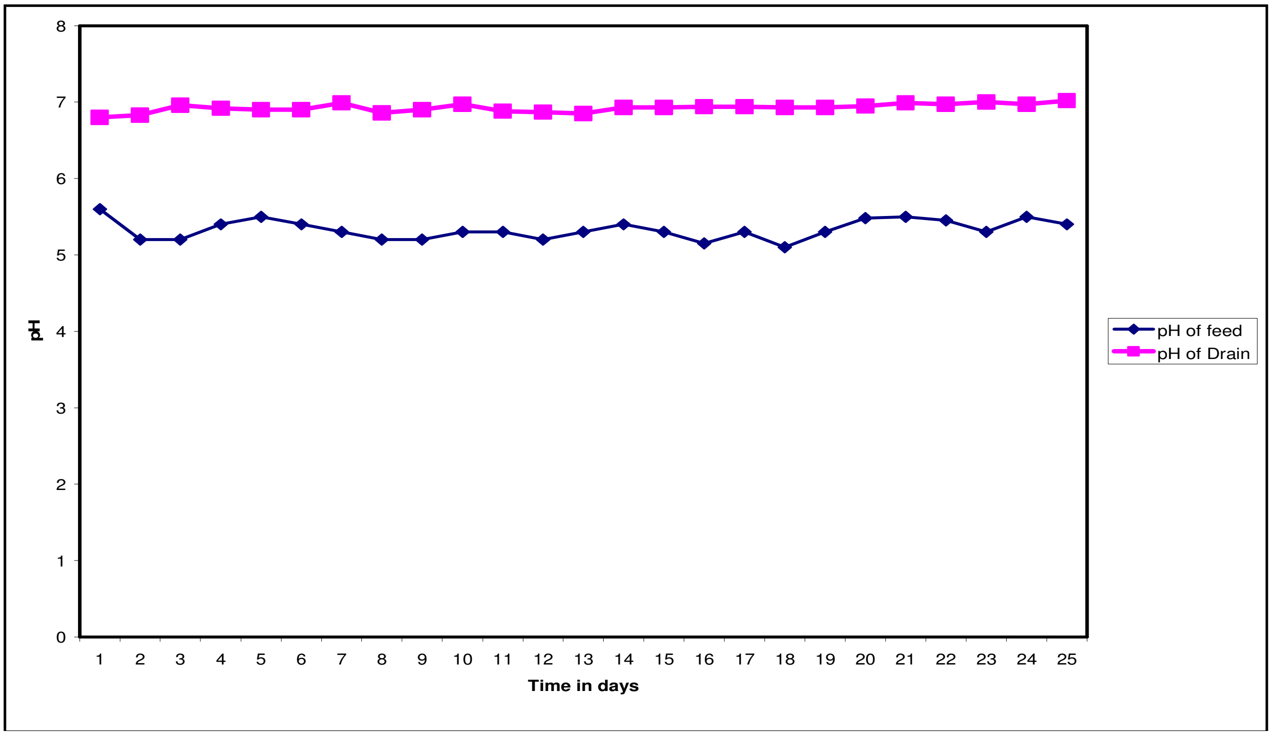

Figure-1
pH profile for OLR 0.25gVS/l.d

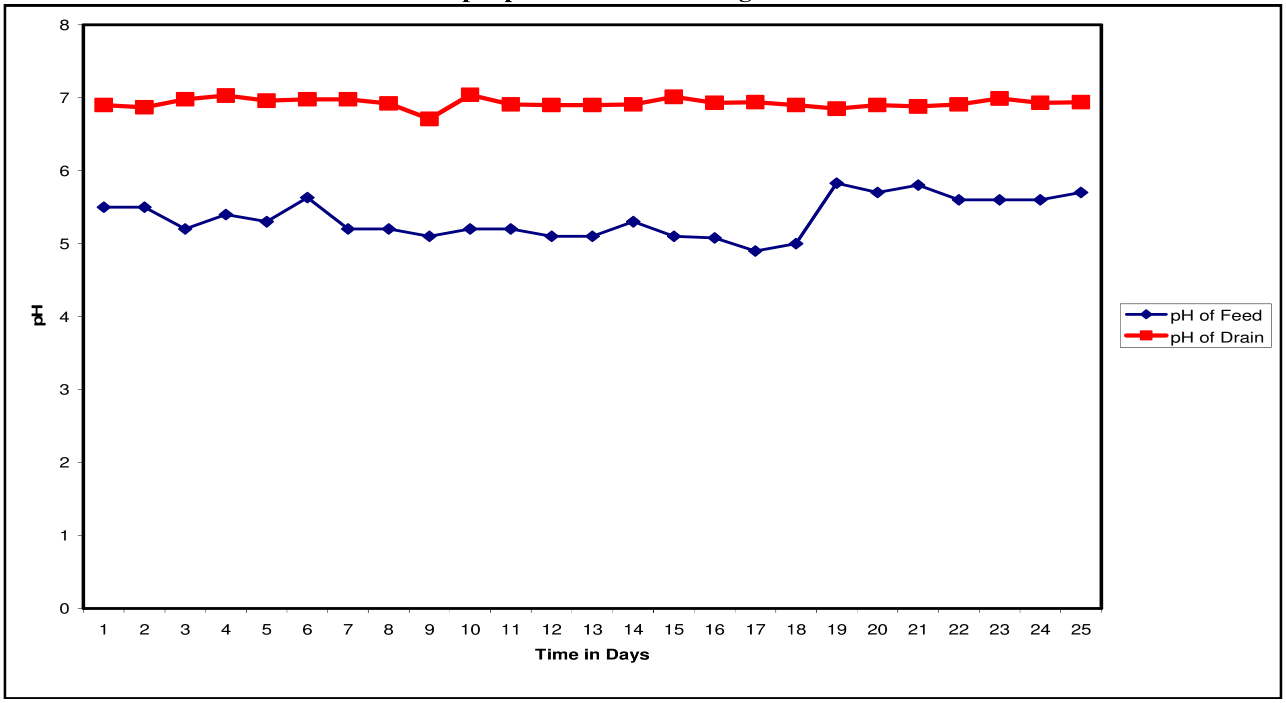

Figure-2
pH profile for OLR 0.5 gVS/l.d

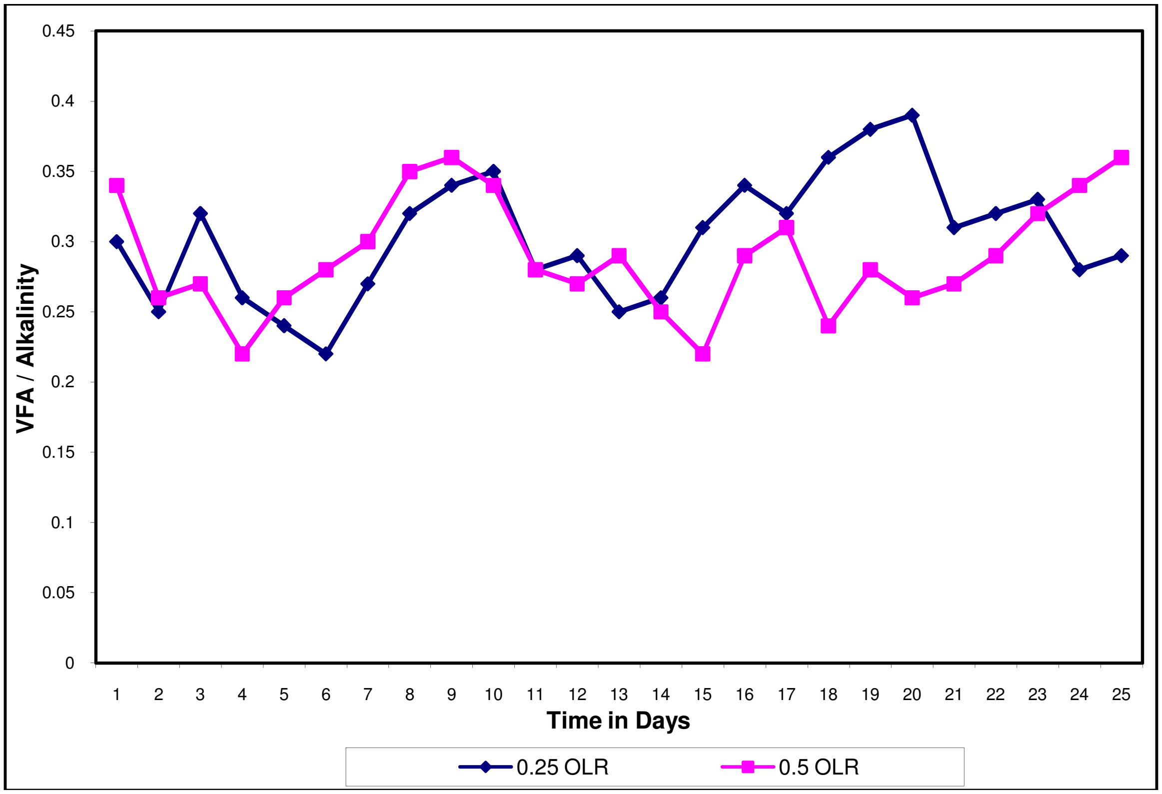

Figure-3
VFA/Alkalinity Ratio in the reactor

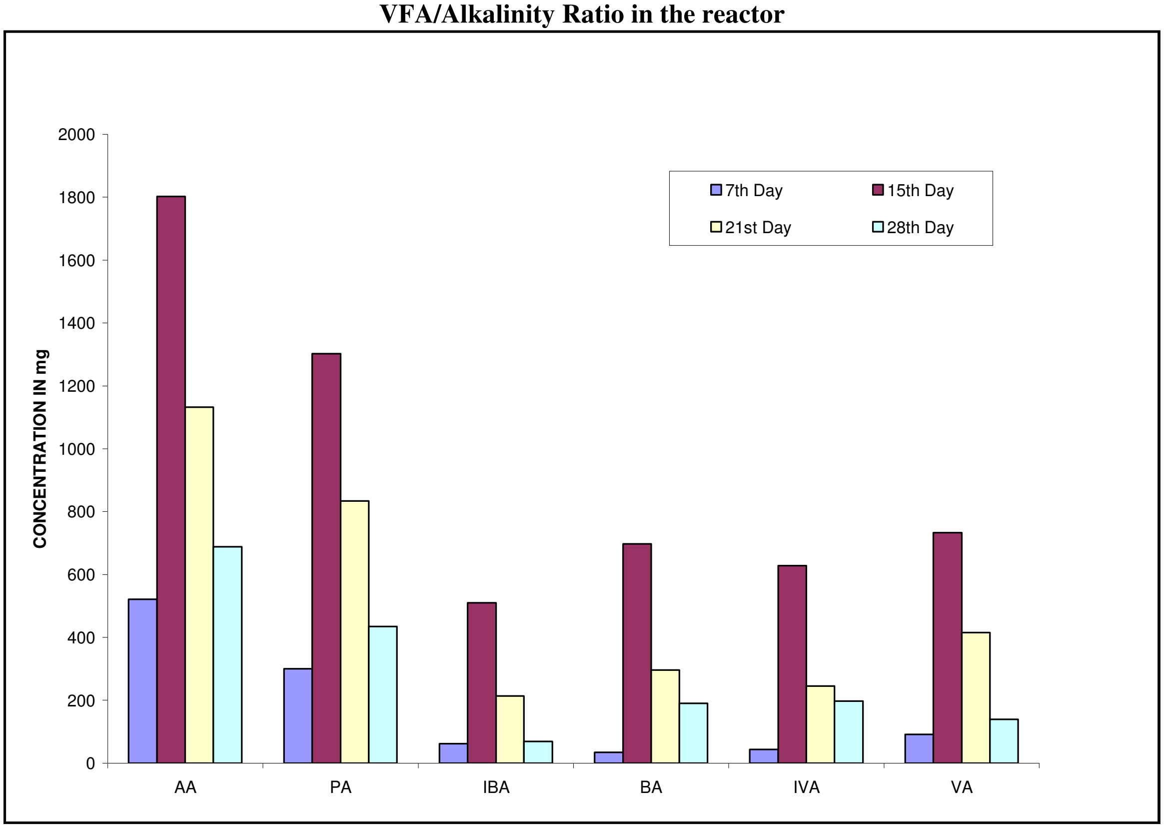

Figure-4
VFA profile for OLR 0.25 gVS/l.d

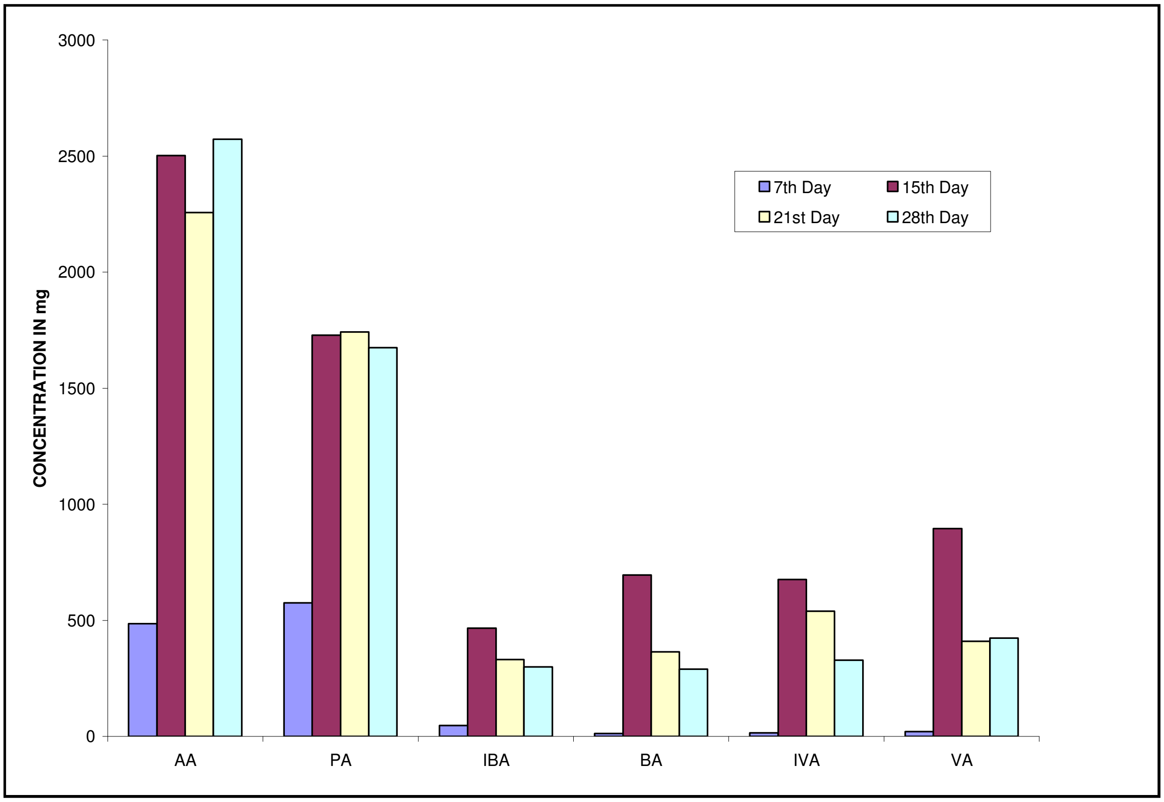

Figure-5
VFA profile for OLR 0.5 gVS/l.d

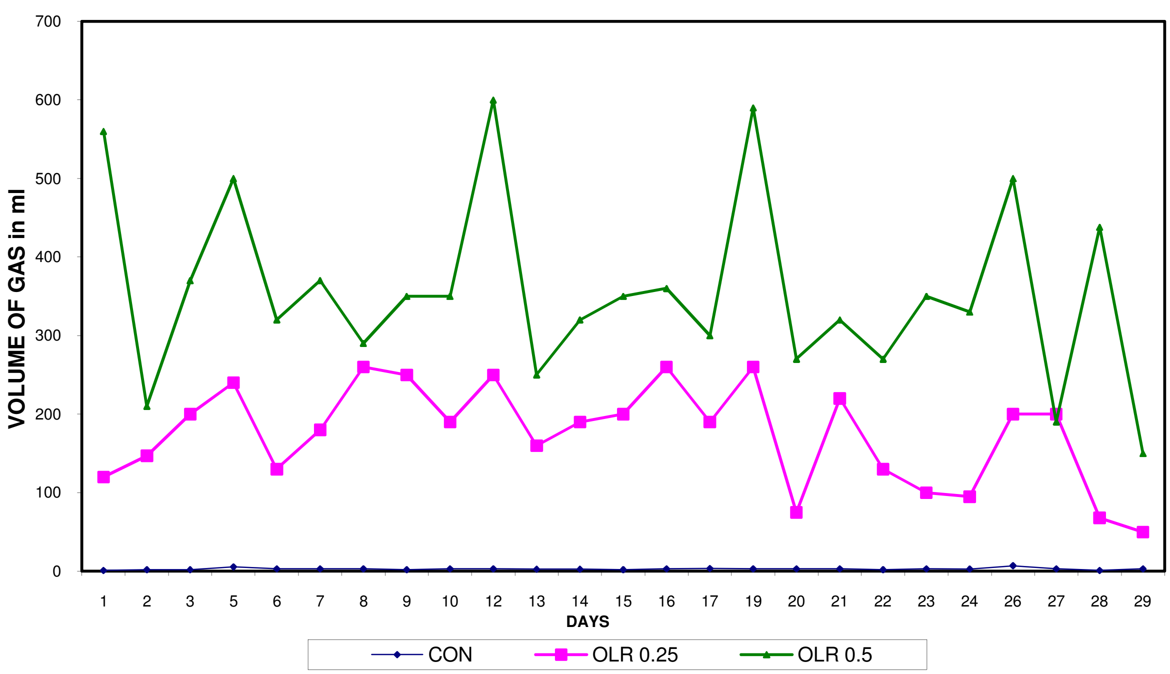

Figure-6
Daily Biogas Production

Conclusion

Anaerobic digestion of vegetable waste has been carried out in a laboratory scale reactor with a HRT of 25 days and an OLR of 0.25 and 0.5 gVS/l.d. The stability of the reactor was justified with the pH, VFA/alkalinity ratio values, predominant presence of acetic acid in the drain and ratio of propionic acid to acetic acid values. pH, TS and VS conversion and gas production observed in the reactor has confirmed that VFA profile prevailed is favorable for sustainable methanogenesis process. The high specific gas production (biogas yield) based on TS and VS added shows that the mixture of vegetable wastes containing high carbohydrates are amenable to anaerobic digestion process and can be effectively converted into biogas with the given organic loading rate. Based on these observations further studies are in progress in continuous reactors for higher OLR. But rapid acidification of vegetable waste due to their lower pH is becoming a problem for the higher OLR.

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Reference

1. Gunaselan N.V., Anaerobic digestion of biomass for methane production: a review, *Biomass and Bioenergy,* **13** , 83 – 11**(1997)**
2. Nirmala B., Deepak S and Sunil K., Biomethanation of Banana peel and Pineapple waste, *Bioresource Technology*, **58,** 73-76 **(1996)**
3. Bouallagui H., BenCheikh R., Marouani L. and Hamdi M., Mesophilic biogas production from fruit and vegetable waste in tubular digester, *Bioresour Technol,* **86,** 85-90 **(2003)**
4. Mata. Alvarez J., Cecchi F., llabres P. and Pavan P., Anerobic digestion of the Barcelona central food market organic wastes: plant design and feasibility study, *Bioresour Technol,* **42,** 33-42 **(1992)**
5. Bouallagui H, Haouari O., Touhami Y., Ben Cheik R., Marouani and Hamdi M., Effect of temperature on the performance of an anaerobic tubular reactor treating fruit and vegetable waste, *Process Biochemistry*, **39(12)**, 2143-2148 **(2004)**
6. Viturtia A., Mata-Alvarez J. and Fazzini G., Two phase anaerobic digestion of mixture of fruit and vegetable wastes, *Biological wastes,* **29,** 189-199 **(1989).**
7. Misi S.N. and Forster C.F., Semi-continuous anaerobic co-digestion of agro waste, *Environmental Technology*, **23**, 445-451**(2002)**
8. Ojolo S.J., Bamgboye A.I., Ogunsina B.S. and Oke S.A., Analytical approach for predicting biogas generation in a municipal solid waste anaerobic digester, *Iran. J. Environ. Health. Sci. Eng.,* **5(3),** 179-186 **(2008)**
9. Prema V., Sumitra Devi S. and Krishna Nand., Anaerobic digestion of fruit and vegetable processing wastes for biogas production, *Bioresou. Technol.,* **40**, 43-48 **(1994)**.
10. Knol C.M., Nelson D.D. and De Wart J., Biogas production by anaerobic digestion of fruit and vegetable waste, *J.Sci. Food Agric,* **29,** 822-830 **(1978)**
11. Patil J.H., Molayan Lourdu Antony Raj, Bhargav S. and Sowmya S.R., Anerobic co-digestion of water hyacinth with primary sludge, *Res.J.Chem.Sci,* **1(3),** 72-77 **(2011)**
12. Dhanalakshmi Sridevi V. and Ramanujam R.A. Biogas Generation in a Vegetable Waste Anaerobic Digester: An Analytical Approach , *Res. J.Recent Sci.* **1(3),** 41-47 **(2012)**
13. Bouallagui H., Touhami Y., Ben Cheik R. and Hamdi M., Bioreactor performance in anaerobic digestion of fruit and vegetable wastes, *Process Biochemistry*, **40**, 989-995 **(2005)**
14. Sharma V.K., Testa C., Cornacchia G., Lastella G. and Farina R., anaerobic digestion of semi-solid organic waste available from orthofruit market: Prelimnary experimental results, *Energy Conservation and Management,* **40,** 287 – 304 **(1999)**
15. Callaghan F.J., Wase D.A.J., Thayanithy K. and Forster C. F., Continuous co-digestion of cattle slurry with fruit and vegetable waste and chicken manure, *Biomass and Bioenergy,* **27**, 71-77 **(2002)**
16. Hill D.T., Cobb S.A. and Bolte J.P., Using volatile acid relationship to predict anaerobic digester failure, *Trans ASAE*, **30**, 496-501**(1987)**
17. Nirmala S., Deepak. and Sunil K., Biomethanation of Banana peel and Pineapple waste, *Bioresource Technology,* **58**, 73-76 **(1996)**
18. Lane A.G., Laboratory scale anaerobic digestion of fruit and vegetable solid waste, *Biomass,* **5**, 245-259 **(1984)**
19. Sharma S.K., Mishra I.M., Sharma M.P. and Saini J.S., Effect of particle size on biogas generation from biomass residues, *Biomass,* **17**, 251-263 **(1988)**