





**Table 1:** Typical substrate composition

Parameter	Cow Dung	Tomato waste
Moisture content (% w/w)	86.48	73.665
Total Solids (% w/w)	13.52	26.33
Volatile Solids (% VS/TS)	81.71	94.68
pH	7.1	4.6
Temperature °C	30	30

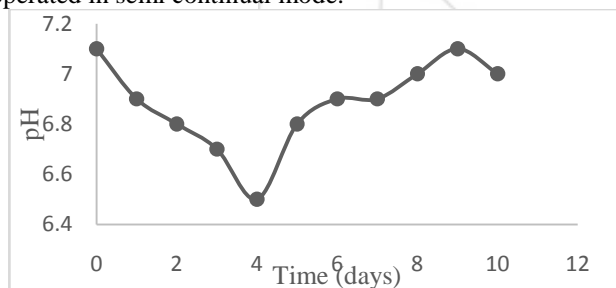
## 5. Results and Discussion

### 5.1 pH variation

pH is one of the most influential parameter in biogas production. pH in an anaerobic digester is the balance of competitive effect of production of VFA that was responsible for acidic nature and production of free ammonia and hydroxyl ions are responsible for basic nature. Higher pH > 7.6 would inhibit methanogenic activity whereas lower pH < 6.3 would hamper biogas production. So balanced rates of production should maintain the necessary pH (6.5 to 7.6)<sup>[14]</sup> for the optimal activity of methanogens. Alkalinity of digester in the range 1500 and 5000 mg/L<sup>[15]</sup> would retain the self-buffering capacity of digester despite the disturbances in the input pH.

#### 5.1.1 Batch Experiment Results

During batch observations, pH was maintained in the optimal range of methanogens as shown in the figure (Fig. 2). During the ninth and 10<sup>th</sup> days of operation, pH was stably fluctuating in the neutral range. It may be described by attaining self-buffering capacity. Thus the digester operated in semi continual mode.

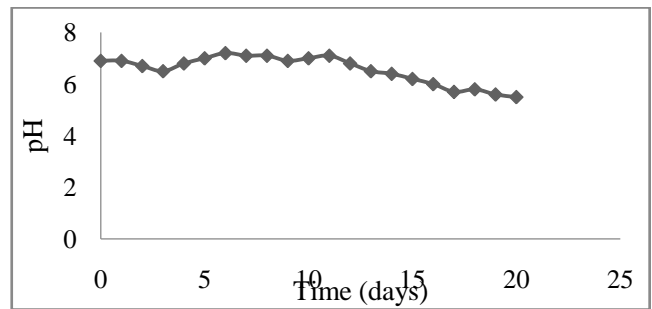


**Figure 2:** pH variation of digester slurry in batch process

#### 5.1.2 Semi continuous experiment results

During the semi continuous study, digester was fed with tomato waste of pH 4.3 and was operated at lower OLR of 1.6 Kg VS/m<sup>3</sup> day and sustained the pH change that was self-buffering (Fig. 3). pH drastically reduced to 5.7 when the operation was at OLR of 5 Kg VS/m<sup>3</sup> day and HRT was 16 days as shown in the figure.

Pallavi et al. <sup>[14]</sup> operated the thermally hydrolysed sludge in the mesophilic range 37-42 °C and SRT 15 and 20 days and the digester performed in pH 6.5 -7.0 in the first 30 days of operation. Alkaline treatment enhanced the pH and was maintained in the optimal range for the remaining days of experiment.



**Figure 3:** Change in pH of the digester slurry with time in semi continuous process

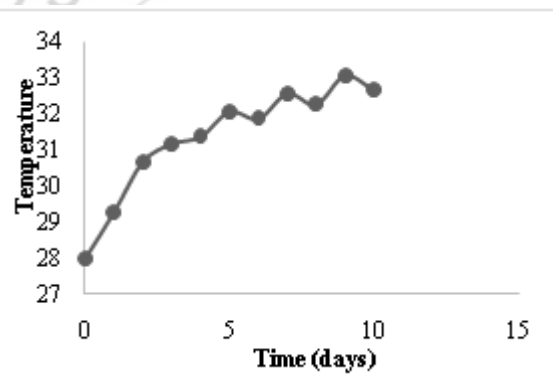
Thus pH control during digestion process were reported often reported by many researchers. Jin-Young Jung et al. <sup>[13]</sup> conducted two stage anaerobic digestion, and had to control the pH of acidogenic digester for maintenance in the range of 6-7 during the initial days of operation for enhanced gas production of s 0.32 m<sup>3</sup> CH<sub>4</sub>/kg COD removed. Adrian et al. <sup>[17]</sup> studied the digestion of mixed agricultural wastes and wheat bran and observed the pH of 5-7 in the first 50 days of operation using wheat bran and 6-7 using mixed agricultural waste. A.E. Ghalay et al. <sup>[16]</sup> operated the digester in two stage process and observed for the effect of pH control, without any pH control he observed the operation of second stage digester reaching neutral pH in the initial stages of operation. However the pH lowered to below 4 in the 20<sup>th</sup> day of operation.

### 5.2 Temperature Variation

Temperature was an important parameter influencing the digestion rate and efficiency. It also indicates the digestion progress in the reactor. Mesophilic digestion in the range of 30- 45 °C is easy and convenient to operate the anaerobic digester.

#### 5.2.1 Batch Experiment Results

In the batch reactor, temperature was recorded as shown in [Fig. 4]. The substrate temperature was 28 °C during the feeding and was consistently rising with time indicating the progress of anaerobic digestion which is exothermic process <sup>[18]</sup>.

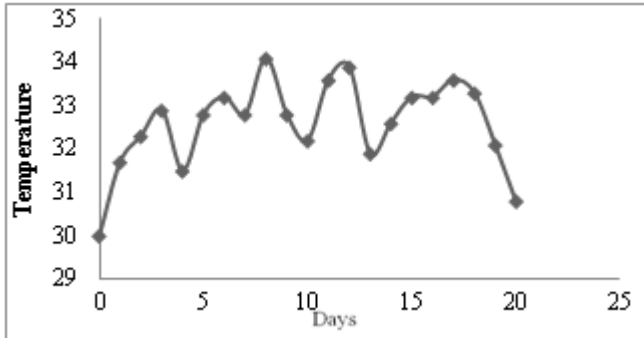


**Figure 4:** Change in temperature of the digester slurry with time in batch process

#### 5.2.2 Semi Continuous Experiment Results

During the semi continuous operation, temperature was fluctuating within 30 °C-34°C and was highest in the second week of operation. Phenomenon can be explained as the increase in the digestion rate and gas production enhanced

the reaction and hence temperature increased during first week of operation. However further increase in the substrate input increased VFA production rate compared to methanogen activity which resulted in the highest temperature record. But due to severe VFA accumulation from the end of second week along with increase in feed input at temperature 28 °C in combined effect led to lowering of temperature to 30 °C that signifies the VFA accumulation (Fig. 5).



**Figure 5:** Change in temperature of the digester slurry with time in semi continuous process

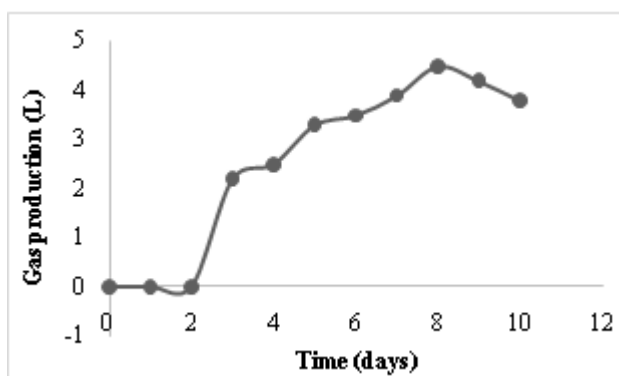
A.E. Ghalay et al. [16] similarly conducted two stage digestion and observed the temperature fluctuations in the range 34 to 37 during 50 days of operation. Adrian et al [17] conducted the digestion of wheat bran and mixed agricultural waste and observed temperature to be varying in 30-40 °C and fall to below 30 °C after 50 days of operation.

### 5.3 Gas Production

Biogas production was influenced by the factors such as HRT, OLR, VS concentration, Temperature and pH of the digester slurry. An optimum collection of parameters would maintain the balance in acidogenic, acetogenic and methanogenic activities and give good gas yield and higher methane concentrations.

#### 5.3.1 Batch Experiment Results

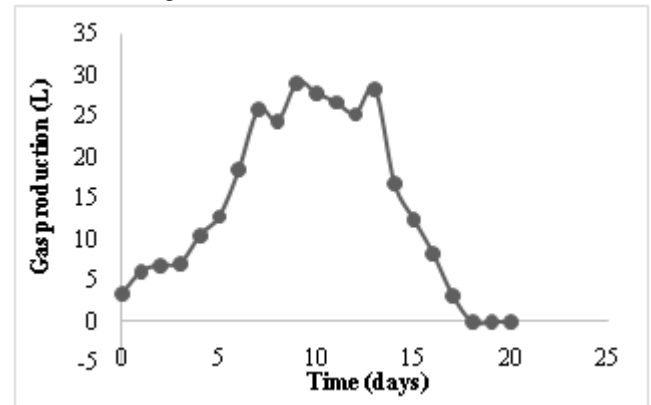
During the batch study, only cow dung was used as substrate with an objective to prepare self-inoculated system with self-buffering capacity. Figure [Fig. 6] illustrates change in gas production with time. Maximum production of 4.5 L was observed in the 8<sup>th</sup> day of installation [Fig. 6]. The production was stable thereafter and the digester was treated with tomato wastes for semi continuous study.



**Figure 6:** Change in gas production with time in batch process

#### 5.3.2 Semi Continuous Experiment Results

During the semi continuous study, the tomato wastes with pH 4.3 were subjected to anaerobic digestion for three weeks at different OLRs that resulted in gas production as shown in the figure 7.



**Fig.7.** Change in gas production with time in the semi continuous process

**Table 2.** Results summary

Duration	HRT	OLR (Kg VS/m <sup>3</sup> day)	VS fraction (w/w)	Average gas production (L/day)	Specific production (L/g VS /day)
1 <sup>st</sup> Week	25	1.6	0.04	9.414	0.13
2 <sup>nd</sup> Week	20	3.5	0.07	26.87	0.17
3 <sup>rd</sup> Week	16	5	0.08	5.84	0.026

High OLR with pH 4.3 resulted in higher Volatile Fatty Acid accumulation and pH fell drastically to 5.8 on 18<sup>th</sup> day of semi continuous operation. Gas production was entirely terminated and yet the digester was active which could be illustrated by the consistent temperatures above 30 °C in the digester even though the temperature of ambience reached 23- 25 °C. Similar case has been encountered in the experiments conducted by BerlianSetarous et al.[9] on 200 liters batch digester which has turned sour (pH < 6) after 3<sup>rd</sup> week of installation and it got stabilized to neutral and attained self-buffering capacity after the 9<sup>th</sup> week of installation.

## 6. Conclusion

Anaerobic digestion of cow dung was conducted in a pilot plant scale and observed for batch production of biogas for two weeks during which the digester achieved inoculum rich characteristics and self-buffering capacity. The digester was next observed in a semi continuous mode for biogas production using tomato wastes at various HRT, Volatile Solid concentrations and OLR. Maximum specific gas production of 0.17 L/g VS/ day was noted during the second week of continuous operation and the digester turned acidic under heavy load of 5 OLR at 16 days HRT and 8 percent Volatile solid concentration. The studies signify that pH of the feed substrate not only influences the gas production and composition but also fixes the limits of operational parameters such as HRT and OLR. Thus using vegetable waste such as tomato waste, efficient biogas production can be achieved if optimum process conditions are maintained in a semi continuous digester.

## References

- [1] PremaVishwanath (22-1991) "Anaerobic digestion of fruit and Vegetable waste for Biogas production" Biogas technology 40 (1992) 43-48
- [2] Velmurgan (2011) "anaerobic digestion of vegetable waste for biogas production in a Fed-Batch reactor" Int. J. emergg. Sci. 1(3) 478-486.
- [3] Bouallagui (2003) "Mesophilic biogas production from fruit and vegetable wastes in atubular reactor" Bio resource Tech.86 85-89.
- [4] AzadehBabee "Anaerobic digestion of vegetable wastes" School of petroleum engg. Tech. Iran
- [5] IM Alfa (2014) "Comparison of evaluation of biogas production from poultry droppings, cow dung and lemon grass" Bio resource Technology 157 2014 270-277.
- [6] Earnest Vinay Prakash (2013) "Biomethanation of vegetable and fruit wastes in co-digestion process" Int. J. emergg. Tech. and Adv. Engg. ISSN 2250-2459.
- [7] Ukpai (2012) "Comparative study of biogas production from cowdung, cow pea, cassava peelings using 45 litres biogas digester" ISSN 0976-8610 AASRFC.
- [8] Adebayo (2014) "Anaerobic digestion of cattle slurry with Maize stalk at mesophilic Temperature" e-ISSN 2320-0847.
- [9] BerlianSitorus (2013) "Biogas recovery from anaerobic digestion process of mixed fruit vegetable wastes". ICSEEA 2012 Energyopedia 32 (2013) 176-182.
- [10] T G Narayani (2012) "Biogas production through mixed fruit waste Biodegradation" Vol. 71 March 2012 PP 217-220.
- [11] IriniAngelidaki (2013) "Methods and apparatus for hydrogen based biogas upgrading" retrieved from <http://www.google.com/patents/WO2013060331A1?cl=en> Google patents WO2013060331 A1.
- [12] Roger Peris Serrano (2011) "Biogas Process Simulation using Aspen Plus" Master Thesis, Department of Chemical Engineering, Biotechnology and Environmental Technology SyddanskUniversitet.
- [13] Jin Young-Jung (2000) "Effect of pH on Phase Separated Anaerobic Digestion" Biotechnol. Bioprocess Eng. 2000, 5: 456-459.
- [14] PallaviBishnoi (2012) "EFFECTS OF THERMAL HYDROLYSIS PRE-TREATMENT ON ANAEROBIC DIGESTION OF SLUDGE" Master Thesis Virginia Polytechnic Institute and State University.
- [15] Ken Schnaars (2012) "What every operator should know aboutanaerobic digestion" retrieved from OperatorsEssentials 82-33WWW.WEF.ORG/MAGAZINE.
- [16] A. E. Ghalay (2000) "Effect of reseeding and pH controlon the performance of a two-stage mesophilic anaerobic digester operating on acid cheese whey" Canadian Agricultural Engineering Vol. 42, No. 4.
- [17] Adrian (2012) "Comparative study on factors affecting anaerobic digestion of agricultural vegetable residues" Bio Technology for Bio fuels 10.1186/1754-6834-5-39 retrieved from <http://www.biotechnologyforbiofuels.com/content/5/1/39>.
- [18] Gregor D (2012) "Anaerobic Treatment and Biogas Production from Organic Waste,Management of Organic Waste" ISBN: 978-953-307-925-7, InTech.
- [19] V. NallathambiGunaseelan (2004) "Biochemical methane potential of fruits and vegetable solid waste feedstocks" Biomass and Bioenergy 26 (2004) 389 – 399.
- [20] APHA, AWWA and WEF, "Standard methods for the examination of water and wastewater", 20th edition, Washington D.C, 1998.
- [21] Jagadish H Patil (2011) "A comparative study on anaerobic co-digestion of water hyacinth with poultry litter and cow dung" International Journal of Chemical Sciences and Applications ISSN 0976-2590. Vol 2, Issue 2, June-2011, pp 148-155.

## Author Profile



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