

# An Experimental Study on Recovery of Energy from Biodegradable Waste with Eichhornia Crassipes in TKRCET, Hyderabad, Telangana

J. Tharrini<sup>1\*</sup>, R. Premsudha<sup>2</sup> and M. Chris Sheba<sup>3</sup>

<sup>1</sup>Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Kuniyamuthur, Coimbatore – 641008, Tamil Nadu, India; tharrinij@skcet.ac.in

<sup>2</sup>Department of Civil Engineering, TKR, College of Engineering of Technology, Medbowli, Meerpet, Hyderabad – 500097, Telangana, India; premi\_jasmine@yahoo.co.in

<sup>3</sup>Department of Civil Engineering, Sri Ramakrishna Institute of Technology, Pachapalayam, Coimbatore – 641010, Tamil Nadu, India; chrisheba@gmail.com

## Abstract

**Objectives:** The work is to recover the energy from food and vegetable waste with water hyacinth and cowdung. **Methods:** The present study focuses the lights to recover energy from organic waste and to adopt safe disposal and conserving natural resources. Laboratory scale batch digesters were set up to find the biogas production potential of Food waste and Vegetable waste with water hyacinth and cow dung. Food waste was collected from our TKR college mess similarly Vegetable waste was collected from the Hyderabad market and prepared for further analysis. Similarly water hyacinth was collected from a Meerpet lake in Hyderabad. Six digesters with varying Vegetable wastes and Food wastes were combined individually by increasing concentrations with fixed amount of water hyacinth and Cow dung by water displacement method. The effect of food waste and vegetable waste concentration on the biogas yield was investigated and the experiments were characterised before and after digestion. **Findings:** Modified Gompertz Equation (MGE) model was fitted to the experimental values and kinetic parameters such as maximum cumulative biogas potential  $B_{max}$  (L/gVS), specific biogas production rate,  $R_b$  ( $L\ gVS^{-1}\ d^{-1}$ ) and lag phase time,  $\lambda(d)$ , were estimated. Experimental values were compared with MGE using MAT LAB. **Applications/Improvements:** From the experimental study observed that an aerobic degradation took place and the biogas produced was measured daily. Kinetic analysis of the biogas production was done and compared & conclusions were drawn.

**Keywords:** Anaerobic Digestion, Food Waste, Modified Gompertz Equation (MGE), Vegetable Waste Kinetic Modelling, Water Hyacinth

## 1. Introduction

Production of biogas from organic waste has gained popularity in recent years and is being adopted for implementation mainly for its energy demand and for the proper disposal of organic waste without causing harm to human beings and to the environment. Organic waste, such as vegetable waste and fruit waste can be easily biodegraded by micro-organisms. Biodegradable wastes

have high moisture content that can be biodegraded by aerobically or an aerobically, by treating in stabilisation ponds, rather than incinerating or composting the waste<sup>1</sup>. Anaerobic digestion of waste produces biogas and reduces the organic waste to a more stable and less harmful<sup>2,3</sup>. This biogas provides energy that can be used for cooking, lighting, and even running of machinery. Food waste and vegetable waste contains large amount of organic solids that can be digested to produce biogas<sup>4-6</sup>. It has become

\*Author for correspondence

increasingly popular to reuse the vegetable and food waste was converting into energy, in order to solve the energy crisis prevalent in today's world. Water hyacinth (*Eichhorniacrassipes*) biomass nowadays occupies all the ponds and lakes which depletes the oxygen, affects the aquatic organisms<sup>7,8</sup>. It is considered to be the worst aquatic weed, due to its rich nitrogen content which is utilized for biogas production<sup>9,10</sup>.

## 2. Materials and Methods

Food Waste (FOW) and Vegetable Waste (VW) and Water Hyacinth (WH) with Cow Dung (CD) as inoculums are the materials used for digestion process.

## 3. Sample Collection and Preparation

Food waste and Cow dung used as seeding material were collected from TKR College mess, Dairy Farm at TKR College Campus, Hyderabad. Vegetable waste was collected from the local market at Kothapet market in Hyderabad, for the anaerobic digestion. Water hyacinth was collected from the nearby Meerpet Lake, Hyderabad, and shredded to a particle size of 2-4 mm. Food waste; vegetable waste and cow dung were dried in sunlight for 5 days and oven dried for 6 hours at 75°C after which it was grinded by using a grind mill separately.

## 4. Experimental Set - Up and Procedure

A 10 digesters of batch mode (5 digester for FOW and 5 digester for VW), each of 2L capacity were used for different proportions of wastes, were connected to polyethylene cans with the help of a cork onto a valve for biogas measurement by liquid displacement method. Composition of food waste and vegetable waste were increased from 50g to 250 g with constant amount of water hyacinth (250g), cowdung (250g) and equal proportion of water to find the optimum mix proportion for maximum gas production. The mix ratio of the digester was starts from 0.2:1:1 to 1:1:1 and its quantity varies 50g to 250g. One digester is kept as control waste, consists equal amount of water hyacinth and cowdung (250g). The pH and temperature was monitored with the help of a probe fitted through the cork, into the digester

at room temperature. The volume of the mixtures was made up to 1.5L with water. The initial characteristics such as pH, TS, VS, C/N and COD for the different waste feedstock were to be analysed as per the Indian standards (IS 10158 - 1982<sup>11</sup> his lab scale digestion was performed for hydraulic retention time of 60 days, until the daily biogas production was very low.

## 4. Kinetic Analysis

Modified Gompertz growth equation was used to analyze the kinetics of biogas production produced by anaerobic digestion as follows<sup>12,13</sup>.

Where BT is the cumulative biogas yield (L/gVS), Bmax is the maximum cumulative biogas potential (L/gVS), Rb is the specific biogas production rate (L gVS-1 d-1), λ is the lag phase time (d), t is the digester time and e is mathematical constant (2.718). The parameters (Bmax, Rb and λ) were estimated by using MATLAB. These parameters are calculated at 95% confidence interval.

$$B_t = B_{\max} e^{-\frac{R_b e}{B_{\max}}(e-t)+1}$$

## 6. Results and Discussion

It was observed that the co-digestion was very slow to begin with, but increased as the digestion progressed. The digestion slowed down and so did the biogas production at the end of observation as well<sup>14,15</sup>. The initial characteristics of the various mixtures of the feedstock were analyzed (Table 1) and the amount of VS and COD reduced due to anaerobic digestion after digestion was established in Table 2.

## 7. Concentration on Biogas Yield

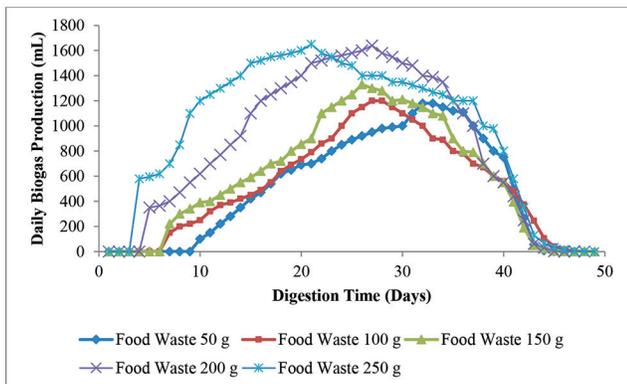
The amount of biogas yield daily increased with the amount of substrate used for digestion (Figures 1 & 2). Since the biogas production is a result of anaerobic digestion of the substrate by the bacteria from the seeding<sup>16</sup>. Biogas produced follows the pattern of kinetic growth curve, also known as bacterial growth curve<sup>17</sup>. Initially it was observed when 50g of food waste and vegetable waste to the control waste has higher yield of biogas than adding 100g to 200g of waste, but lower than the yield when 250g of waste was added, Therefore the addition of 250g of food

**Table 1.** Characteristics of feedstock before digestion

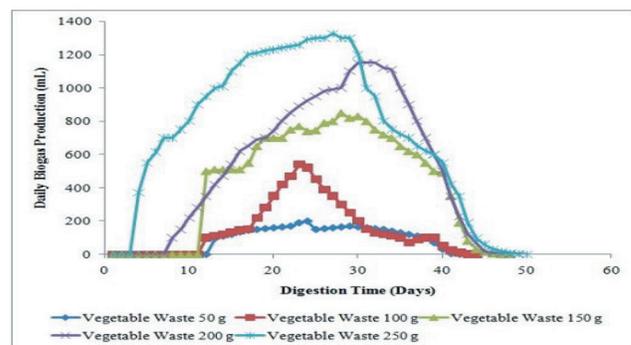
Sample Description	Mix ratio	pH	TOC %	N %	C/N Ratio	TS %	VS %	COD (mg/L)
CW	0: 1: 1	7.05	44	1.79	24.5:1	7.37	85.8	46153.8
FOW <sub>1</sub>	0.2: 1: 1	550	6.37	47.5	1.67	28.4:1	7.43	87.8
FOW <sub>2</sub>	0.4: 1: 1	600	6.41	48.3	1.63	29.6:1	8.11	89.35
FOW <sub>3</sub>	0.6: 1: 1	650	6.89	49	1.57	31.2:1	6.99	90.25
FOW <sub>4</sub>	0.8: 1: 1	700	6.93	50.5	1.55	32.5:1	7.83	93.45
FOW <sub>5</sub>	1: 1: 1	750	6.87	52.08	1.51	34.5:1	7.64	96.35
VW <sub>1</sub>	0.2: 1: 1	6.83	46.08	2	20.2	8.06	82.96	44851.3
VW <sub>2</sub>	0.4: 1: 1	6.67	46.3	2.15	21.5	7.01	83.5	65876.7
VW <sub>3</sub>	0.6: 1: 1	6.49	45	1.96	22.8	7.24	80.5	60000
VW <sub>4</sub>	0.8: 1: 1	6.3	46.7	1.9	23.4	6.49	84.2	51336.9
VW <sub>5</sub>	1: 1: 1	6.24	47.5	1.93	24.5	7.81	85.5	59360.7

**Table 2.** Amount of VS and COD reduced due to anaerobic digestion

Sample Description	After digestion		g VS Reduced	% VS Reduced	% COD Reduced
	gVS	COD (mg/L)			
CW	16.07	34991.90	15.55	49.2%	24.2%
FOW <sub>1</sub>	7.72	35492.51	28.16	78.5%	31.5%
FOW <sub>2</sub>	7.90	45653.65	35.58	81.8%	32.8%
FOW <sub>3</sub>	4.62	36657.18	36.38	88.7%	33.7%
FOW <sub>4</sub>	1.58	36667.39	49.64	96.9%	39.9%
<b>FOW<sub>5</sub></b>	<b>23.19</b>	<b>61852.45</b>	<b>32.02</b>	<b>58.0%</b>	<b>23.0%</b>
VW <sub>1</sub>	11.52	29743.29	25.26	68.7%	33.7%
VW <sub>2</sub>	8.25	40512.20	26.87	76.5%	38.5%
VW <sub>3</sub>	7.18	38373.91	30.70	81.0%	36.0%
VW <sub>4</sub>	3.81	33347.03	34.44	90.0%	35.0%
<b>VW<sub>5</sub></b>	<b>26.04</b>	<b>42739.73</b>	<b>24.04</b>	<b>48.0%</b>	<b>28.0%</b>



**Figure 1.** Daily Biogas produced by the different mixtures of food waste.



**Figure 2.** Daily Biogas produced by the different mixtures of vegetable waste.

waste to the control waste impacted the biogas production considerably, The various mixtures were digested under anaerobic conditions and the daily biogas production was observed. It was found that the daily biogas production reached its maximum around 27 – 30 days for vegetable waste respectively, under optimum conditions.

## 8. Modified Gompertz Modelling

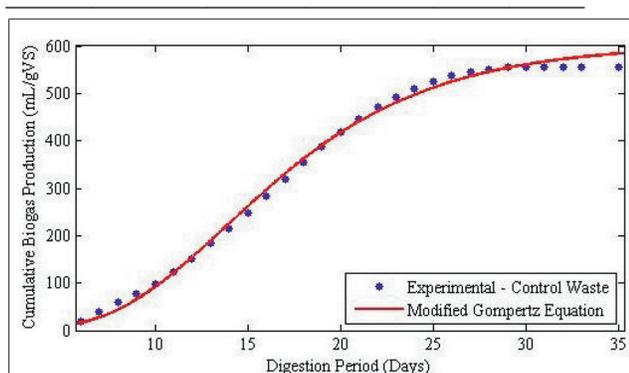
The results of fitting the experimental data to the Modified Gompertz Model as shown by the R<sup>2</sup> values in Table 3 and shown for the various compositions in Figures 3 to 15. The B<sub>max</sub> value calculated by Modified Gompertz Equation (MGE) for the digestion of 250g of food waste is found to be higher than the control waste

and the rest of the mixture compositions (Figure 8). It observed from the study effect of increasing proportions of lignocellulosic co-substrate with the readily available biodegradable substrate increase the yield of biogas. The Vegetable waste 250g yielded maximum amount of biogas yield experimentally and is shown in (Figure 15) to have a slightly higher potential to reach maximum biogas production in minimum amount of incubation period. This is in correlation with the biogas yield determined from the experimental data.

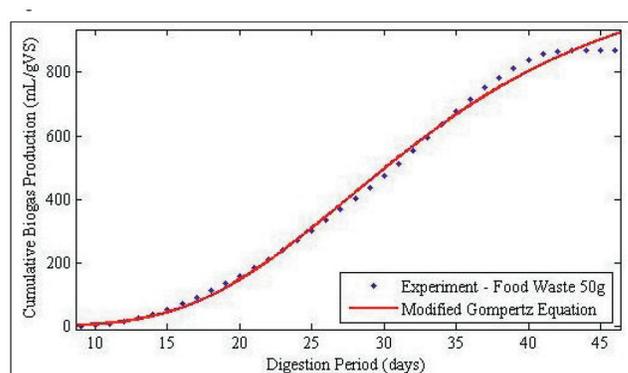
The cumulative biogas production from 250g of FOW combined with WH and CD for a retention period of 50 days is about 1.27 m<sup>3</sup>/(Kg\*day). Similarly, the cumulative biogas production from 250g of VW combined with WH and CD for a retention period of 50 days is about 1.0 m<sup>3</sup>/(Kg\*day).

**Table 3.** Biogas production fit with the modified gompertz equation

Mixture	Biogas Yield (mL/(gVS))	Modified Gompertz Equation			R <sup>2</sup>
		B <sub>max</sub> (mL/(gVS))	R <sub>m</sub> (mL/ (gVS*d))	λ (d)	
CW	556.6	602.7	36.21	7.776	0.9971
FOW <sub>1</sub>	867.63	1104	37.52	16.77	0.9964
FOW <sub>2</sub>	717.82	818.4	30.42	14.64	0.9972
FOW <sub>3</sub>	794.13	898.7	34.01	13.8	0.9958
FOW <sub>4</sub>	820.42	931.7	33.08	11.47	0.9970
<b>FOW<sub>5</sub></b>	<b>1487.15</b>	<b>1671w</b>	<b>52.95</b>	<b>8.03</b>	<b>0.9983</b>
VW <sub>1</sub>	155.62	179.5	7.458	14.62	0.9983
VW <sub>2</sub>	244.01	249.5	16.92	16.15	0.9983
VW <sub>3</sub>	650.94	739	28.04	14.39	0.9975
VW <sub>4</sub>	737.36	848.5	31.56	14.92	0.9956
<b>VW<sub>5</sub></b>	<b>1528.13</b>	<b>1681</b>	<b>56.71</b>	<b>8.304</b>	<b>0.9983</b>



**Figure 3.** MGE fit for CW.



**Figure 4.** MGE fit for 50g of FoW.

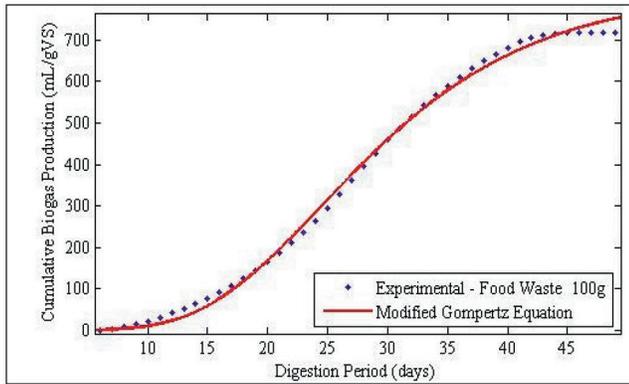


Figure 5. MGE fit for FOW<sub>2</sub>

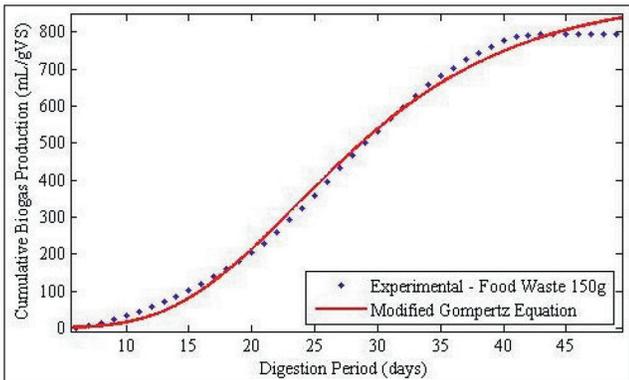


Figure 6. MGE fit for FOW<sub>3</sub>

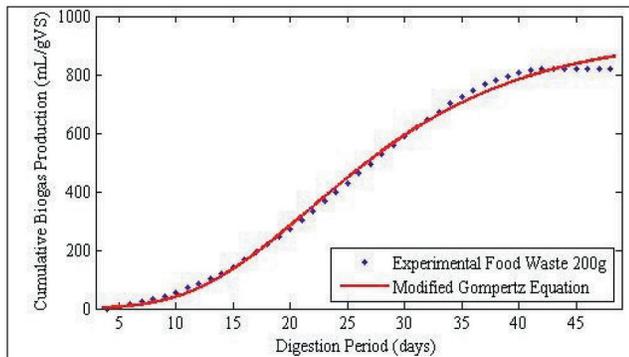


Figure 7. MGE fit for FOW<sub>4</sub>

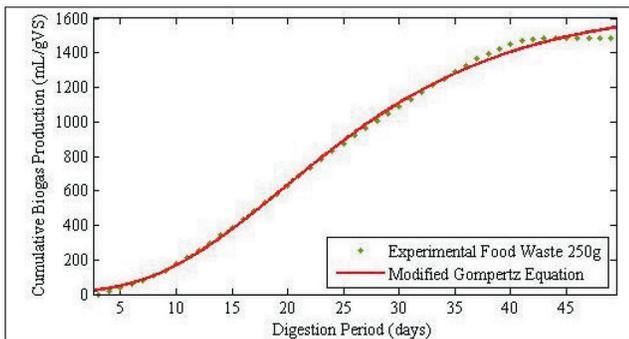


Figure 8. MGE fit for FOW<sub>5</sub>

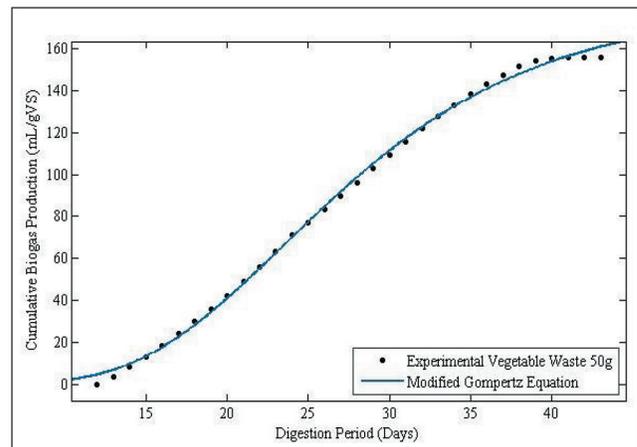


Figure 9. MGE fit for VW<sub>1</sub>

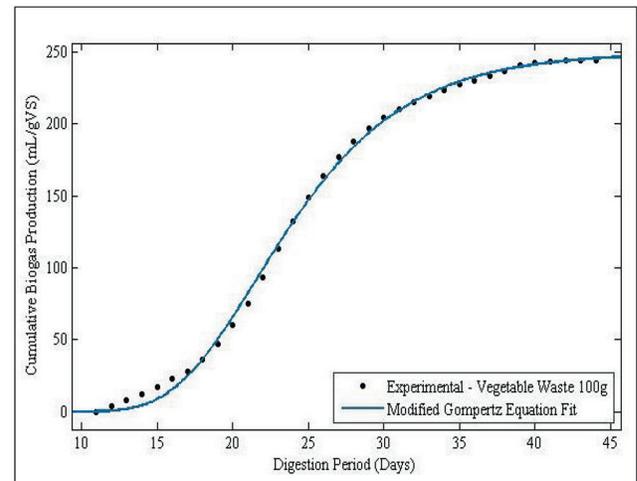


Figure 10. MGE fit for VW<sub>2</sub>

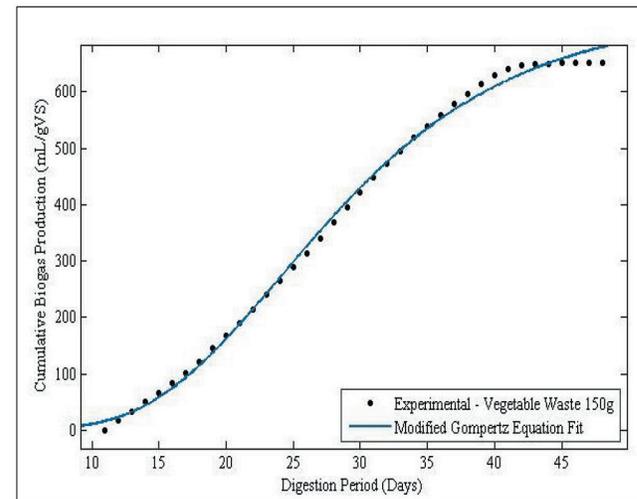


Figure 11. MGE FIT for VW<sub>3</sub>

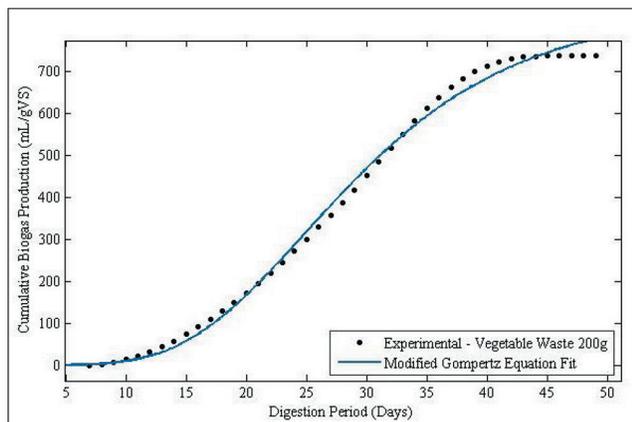


Figure 12. MGE fit for  $VW_4$ .

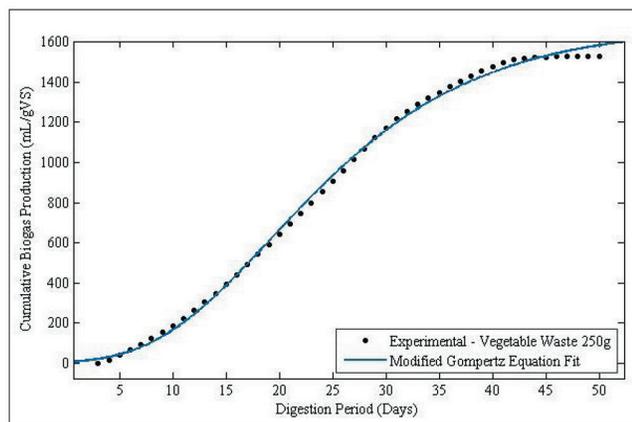


Figure 13. MGE fit for  $VW_5$ .

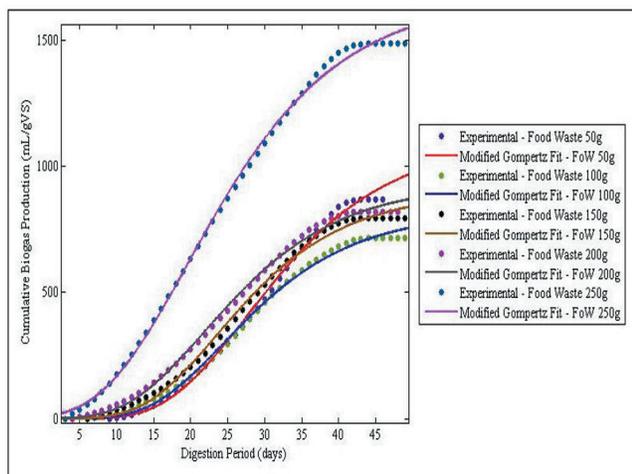


Figure 14. MGE fit for the various proportions of food waste.

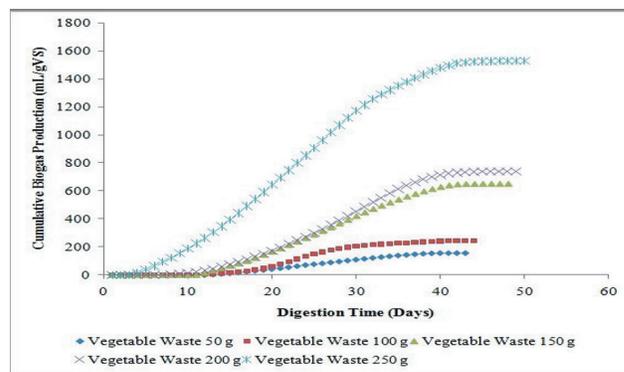


Figure 15. MGE fit for the various proportions of vegetable waste.

## 9. Conclusions

From the experimental study it was observed that the food waste: water hyacinth: cow dung, vegetable waste water hyacinth: cow dung of mix ratio 1: 1: 1 (250g+250g+250g) produced the biogas at the fastest rate than the other ratios fifth digester. It was observed that the percentage of COD removal is more in  $FOW_5$  (23%) and  $VW_5$  (28%). This is on account of the optimum concentration of organic solids and the microbial activity in the digester. Kinetic modelling of the biogas production using modified Gompertz equation show that the  $FOW_5$  &  $VW_5$  correlated best with model and had the desired constants i.e. maximum cumulative biogas potential  $B_{max}$ , 1671L/gVS, 1681L/gVS, specific biogas production rate,  $R_b$  52.95L/gVS $^{-1}d^{-1}$ , 56.71L/gVS $^{-1}d^{-1}$  and lag phase time,  $\lambda$  (d) were, 8.03 days, 8.34 days respectively. Control waste  $B_{max}$ , 556.6 L/gVS,  $R_b$ , 36.21 L/gVS $^{-1}d^{-1}$  and lag phase time,  $\lambda$  (d) were, 7.776 days. From this study it was observed that equal composition of food and vegetable waste with water hyacinth and cowdung is the optimum mixture to produce maximum yield with minimum period.

## 10. References

1. Velmurugan B, Ramaujam AR. Anaerobic digestion of vegetable wastes for biogas production in a fed-batch reactor, International Journal of Energy Science. 2011; 1(3):478–86.
2. Zhang Q, Hu J, Lee DJ. Biogas from anaerobic digestion processes: Research updates, Renewable Energy. 2016; 98:108–19. <https://doi.org/10.1016/j.renene.2016.02.029>.
3. Li D, Liu S, Mi L, Li Z, Yuan Y, Yan Z, Li X. Effects of feedstock ratio and organic loading rate on the anaerobic

- mesophilic co-digestion of rice straw and cow manure, *Bioresource Technology*. 2015; 189:319–26. <https://doi.org/10.1016/j.biortech.2015.04.033>. PMID: 25909453.
4. Tamilselvan D, Kannan M, Lawrence P. Experimental and theoretical study on the effect of solid concentration on biogas production from food waste, *International Journal of Advanced Engineering Technology*. 2016; 7(2):694–96.
  5. Zhang C, Xiao G, Peng L, Su H, Tan T. The anaerobic co-digestion of food waste and cattlemanure, *Bioresource Technology*. 2012; 129:170–76. <https://doi.org/10.1016/j.biortech.2012.10.138>. PMID: 23246757.
  6. Chen X, Yan W, Sheng K, Sanati M. Comparison of high-solids to liquid anaerobic co-digestion of food waste and green waste, *Bioresource Technology*. 2014; 154:215–21. <https://doi.org/10.1016/j.biortech.2013.12.054>. PMID: 24398149.
  7. Chanakya HN, Borgaonkar S, Meena G, Jagadish KS. Solid phase biogas production with garbage or water hyacinth, *Bioresource Technology*. 1993; 46(3):227–31. [https://doi.org/10.1016/0960-8524\(93\)90125-U](https://doi.org/10.1016/0960-8524(93)90125-U).
  8. Momoh OLY, Nwaogazie LI. Effect of waste paper on biogas production from co-digestion of cow dung and water hyacinth in batch reactors, *Journal of Applied Sciences and Environmental Management*. 2008; 12(4):95–98. <https://doi.org/10.4314/jasem.v12i4.55245>.
  9. Patil JH, Raj M, Gavimath C, Hooli VR. A comparative study on anaerobic co-digestion of water hyacinth with poultry litter and cow dung, *International Journal of Chemical Science and Application*. 2011; 2(2):148–55.
  10. Patil JH, Raj MLA, Bhargav S, Sowmya SR. Anaerobic co-digestion of water hyacinth with primary sludge, *Research Journal of Chemical Sciences*. 2011; 1(3):72–77.
  11. IS 10158 - 1982, Indian Standard - Methods of analysis of solid waste (Excluding Industrial Solid Wastes). Date accessed: 1982. <https://archive.org/details/gov.in.is.10158.1982/page/n3>.
  12. Ghatak MD, Mahanta P. Kinetic assessment of biogas production from lignocellulosic biomasses, *International Journal of Engineering and Advanced Technology*. 2014; 3(5):244 Date accessed: 1982.49.
  13. Zwietering MH, Jongenburger I, Rombouts FM, van't Riet K. Modeling of the bacterial growth curve, *Applied and Environmental Microbiology*. 1990; 56(6):1875–81.
  14. Budiyo IS, Sumardiono S. Effect of total solid content to biogas production rate from vinasse, *International Journal of Engineering Transactions B: Applications*. 2014; 27(2):177–84. <https://doi.org/10.5829/idosi.ije.2014.27.02b.02>.
  15. Pahl O, Firth A, MacLeod I, Baird J. Anaerobic codigestion of mechanically biologically treated municipal waste with primary sewage sludge - A feasibility study, *Bioresource Technology*. 2008; 99(9):3354–64. <https://doi.org/10.1016/j.biortech.2007.08.027>. PMID: 17904361.
  16. Ganesh R, Torrijos M, Sousbie P, Lugardon A, Steyer JP, Delgenes JP. Effect of increasing proportions of lignocellulosic cosubstrate on the single-phase and two-phase digestion of readily biodegradable substrate, *Biomass and Bioenergy*. 2015; 80:243–51. <https://doi.org/10.1016/j.biombioe.2015.05.019>.
  17. Usman G, Ajinomoh CS, Muhammad JA, Momoh OR. Reducing the hydraulic retention and lag times for the degradation of simulated organic fraction of municipal solid wastes using carbon to nitrogen ratio proportioning, *International Journal of Advancements in Research and Technology*. 2015; 4(2):100–06.