International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 5, pp: 404-408 www.ijaem.net ISSN: 2395-5252

Factor Analysis of Anaerobic Processing of Municipal Organic Wastes to Biogas Using Integrated Bioreactor

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Date of Submission: 16-08-2020 Date of Acceptance: 01-09-2020

ABSTRACT: The study of anaerobic processing of municipal waste to biogas was carried out using an integrated bioreactor. The data's (volume of gas) generated was subjected to software programs (MATLAB and EXCEL 2007). The results showed a chemical oxygen demand(COD) reduction at three different organic loading rates (OLR) ranged from 93% for the CSTR to 97% for the UASB. Model showed the dependence of y on OLR when the organic matter is completely converted to biogas.

KEYWORDS: Biogas, Bioreactor, Digester, Factor, Integrated, Analysis, Waste.

I. INTRODUCTION

The European community has agreed target on renewable energy. This agreement establishes high standards for the member state which aimed at 20% share for renewable energy by the year 2020 (European Commission Energy, 2010)(1). Among the various alternative of source of renewable energy, biogas has superior advantages which recommends it for exploitation. The process requires less capital investment per unit production cost compared to other renewable energy system such as hydro, solar and wind energy, the effluents from the biogas process can be used as organic fertilizer.(2,3).

The method has the potential to keep environment clean. However, in Nigeria the operation of these digesters for the production of biogas have not been successful, for instance, the human wastes plant at Fodder farm of the National Animal Production Research Institute Zaria (NARPI) was reported to have low gas yield. It has inherent problems problem of building up volatile fatty acids within a short period. The cow dung biogas plants at May Flower Secondary School Ikene, Ogun State is facing the same challenge (4,5).

This is because of factors such as Hydraulic Retention Time (HRT) organic loading rate (OLR) and flow dynamics were poorly designed (6). The aim of the research is to analyzed the factors in anaerobic processing of municipal organic waste to biogas using integrated bioreactor where factor such as HRT, OLR, P^H, and flow dynamics will lead to more efficient biogas yield, and also to develop a comparable model describing the parameters obtained and test the models against literature and practical value(7).

II. MATERIALS AND METHODS

Preparation of Substrate

The municipal organic waste (MSOW) was carefully segregated from the central market in Owerri Imo state, Nigeria. Glass, plastic, metal fractions were removed. Portion compromising of vegetable matter were selected and dried in a vacuum oven at 60^0C and reduced to 500um. This fraction was used in the bioreactor.

Feed Production

The slurry was prepared by mixing 10Kg MOW 500um mesh in 250l of water in a reservoir tank. The catalyst of cow rumen was prepared by mixing of 5L of water with 2Kg rumen content, 2 liters filtered through nylon cloth was used in the 250l slurry contained in the reservoirs tank, the slurry was pumped into a 350l feed tank as shown in fig 1. A schematic representation of the bioreactor configuration as shown in fig 1 which comprises

Module 1 - Up flow Reactor
Module 2 - Twin Down flow Reactor
Module 3 – Continuous stirred Tank Reactor

The module 1 Up flow reactor is 76 liters in capacity and has a meeting pump which goes at 0.5 per minute. Module 2 has a capacity of 62.8 liters. Both vessels are stirred by a down flow fluid process while the module 3 has a capacity of 26 liters with a geared electric motor which rotate through pulleys to a speed of 40 rounds per minute.

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III. RESULTS and DISCUSSION

Table 1: Experimental and Derived values of Bioreactor Operation OLR1 Module 1

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Theoretical Methane Yield (L/day) Theoretical	0	142.47	117.23	97.69	79.90	65.70	52.10	40.85	31.97	23.09	15.98	11.24	8.28	4.73	4.44
Cumulate Methane Yield (L/day)	0	52	124	214	316	426	544	667	797	931	1069	2212	2357	2505	2653

Table 2: Experimental and Derived values of Bioreactor Operation OLR1 Module 2

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Theoretical Methane Yield (L/day) Theoretical	0	103.02	79.92	60.98	44.99	32.56	26.05	19.54	14.20	10.06	8.28	8.28	7.6	7.64	7.6
Cumulate Methane Yield (L/day)	0	32	86	154	232	320	416	518	624	735	849	964	1079	1194	1194

Table 3: Experimental and Derived values of Bioreactor Operation OLR1 Module 3

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Theoretical Methane Yield (L/day) Theoretical	0	142.47	97.69	74.00	58.62	47.95	39.07	36.12	24.86	21.31	17.76	15.98	14.21	13.02	10.65
Cumulate Methane Yield (L/day)	0	14	54	110	180	163	259	365	481	603	725	849	981	1114	1248

The results of methane yields were presented in table 1 to 3 at one day period intervals. The initial runs attempting an hourly harvesting of gas yield failed due to the fact that the rate of production was faster than the arrangement for monitoring and collection. In all cases an HRT of between 13 and 14days was observed to be the limit for any further breakdown of organic matter.

Figs 1 - 3 are plots of table 5, the plots were done using MATLAB version 7.9, the yield of methane were expressed as a power series. The table 5 shows the observed methane yield against HRT for ORL 1 Modules 1,2 and 3. The values were represented in table 4 below. The R^2 value indicated disparity between the experimental and theoretical values.

Table 4: Methane Yield as a Power Function of Seventh Order.

Organic Loading Rate (OLR)	Module	Functional Equation
	1	$Y=8.4e\text{-}005*x^7\text{-}0045*x^6+0.1x^5\text{-}1.1*x^4+7.5*x^3\text{-}29*x^2+72*x+0.35$ $R^2=0.9987$
	2	$y=7.2e\text{-}005*x^6+0.0047*x^5\text{-}0.11*x^4+1.3*x^3+89*x^2+40*x\text{-}0.043$ $R^2=0.9998$
	3	$Y=0.015*x^3\text{-}1.1*x^2+23x\text{-}2.70$ $R^2=0.9986$

Table 5: Observed Methane yield as against HRT, OLR1, Modules1, 2, 3.

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
HRT. OLR 1 Module 1	0	51	71	88	100	108	116	121	128	131	136	140	142	145	145
HRT. OLR 1 Module 2	0	56	80	94	106	116	125	131	137	140	144	145	145	145	145
HRT. OLR1 Module 3	0	51	71	88	100	108	116	121	128	131	136	138	140	145	149

Table 6: Methane Yield potentials of bioreactor Module 1, 2 and 3

	Module	Methane Yield (mL/STP)
Organic loading Rate	1	23,550
	2	52,915
	3	28,980

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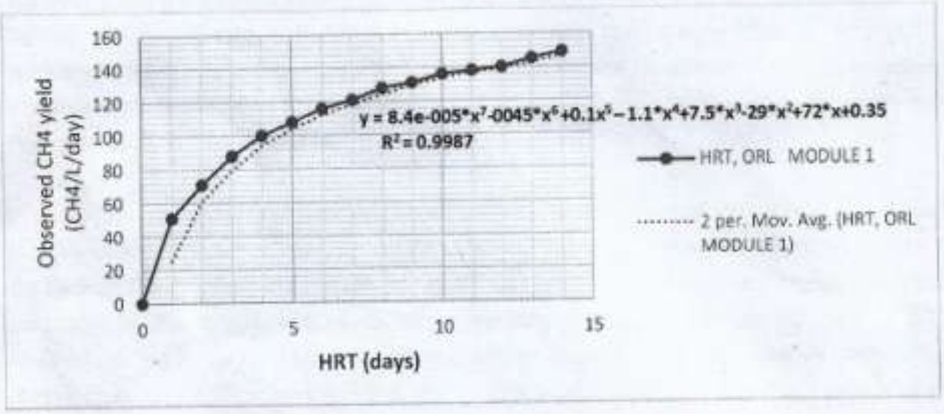


Fig 1: Graph of Observed Methane yield against HRT. ORL1 Module I

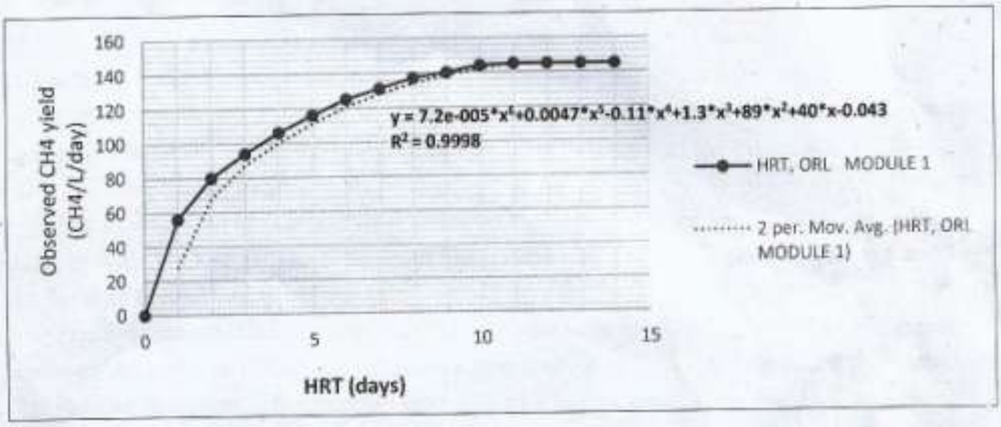
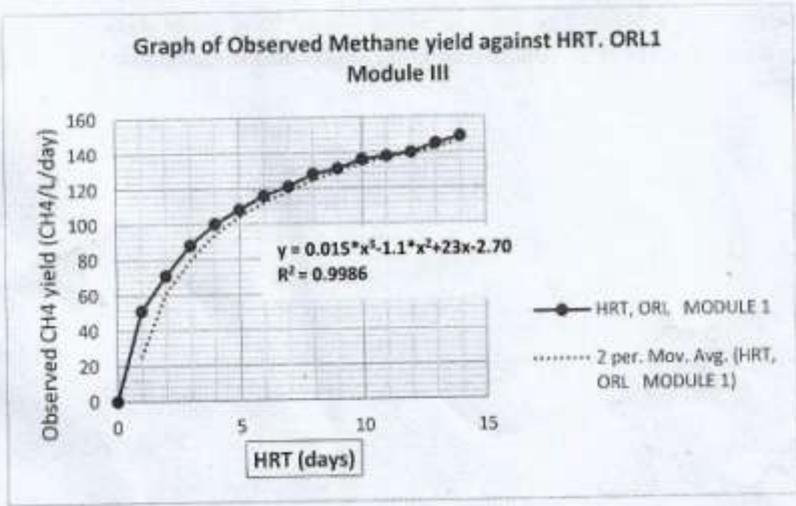


Fig 2: Graph of Observed Methane yield against HRT. ORL1 Module II



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Fig,3. Graph of observed methane yield against HRT. ORL module II

In general the graph of the first group shows a smooth steady increase until a steadystate conditions are achieved, in the second group, the rate is faster and less controllable. The parameters which influence progression to steady state and maintenance are expressed in the variable x. The variables in this case are factors which influence methanogenic species growth rate. The results in table in table 6.

The predicated values show that about 50% of methane gas was produced by Module 2 twin vessel bioreactor considering its substrate working volume of 62.8L as against 75L for each of the standard bioreactor Module 1 and 3. Comparatively, the higher methane gas generated by Module 2 twin vessel bioreactor was probably due to the integrated flow and scale of mixing patterns. This was corroborated by experimental investigation (8) which shows that a combination of impellersproduced more efficient performance in bioreactors.

IV. CONCLUSION AND RECOMMENDATIONS

The factor Analysis Anaerobic Processing of Municipal organic Waste of biogas with a bioreactor Module I,II and III was studied, the performances of the bioreactor was based on accumulative biogas yield

The methane yield was a power series of the seventh order gave high yield of 52,915mL/STP with Module II. The predicated value was shown that 50% of the methane gas was produce by Module II twin vessel bioreactor.

The R-values obtained by the curve fitting software were employed to show close agreement between the observer value and theorical postulate. It is therefore concluded that although the module II system if fractionally slow but with the higher cumulative yield of methane. It is an entire new concept in reactor design and processing, having never been described in available literature.

Finally, there is need to further investigate rigorously the turbulence characteristic in fluid flowing in the work using state of arts method such as particle image velocimetry and computational fluid dynamic software in order to characterize module II twin bioreactors.

Abbreviation and nomenclature

ORL - Organic Loading rate (mg/L)
HRT - Hydraulic retention time (t)
UASB - Up flow anaerobic sludge
CSTR- Continuous Stirred tank rector
MOSW – Municipal Solid Organic waste
COD – chemical oxygen demand (mg/l/

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