BIOGAS PRODUCTION BY CO-DIGESTION OF MUNICIPAL SOLID WASTE GENERATED FROM VEGETABLE MARKET AREA AND SHEEP DUNG

S. Sankaran*[1], S.Sivaprakasam[3] and T. Velayutham[2]

*[1] *Assistant Professor in Civil Engineering, University College of Engineering, Anna University, Thirukkuvlai – 610 204, Tamilnadu, India Email:- ersansme@gmail.ocm*

[2 & 3] *Assistant Professor in Civil Engineering, FEAT, Annamalai University, Annamalainagar – 608 002, Tamilnadu, India*

ABSRACT: This research investigates the synthesis of biogas generation from municipal solid waste generated from the vegetable market, co-digested with sheep dung through anaerobic digestion in batch digesters. The batch experiment was carried out for a period of 50days, at room temperature and co-digested with Sheep dung at varying concentration of 10%, 20% and 30%. The performance of the digesters was evaluated by measuring the daily biogas generation. Effect of organic solids concentration and digestion time on biogas yield was studied. The measured volume of biogas yield from the reactors, co-digested using Sheep dung as inoculum were 256.45ml/gVS, 385.65ml/gVS and 478.9ml/gVS. The biogas generation was 0.227, 0.384 and 0.423 m3/day/m3 of the digester volume for the sheep dung innoculum variation of 10%, 20% and 30% respectively.

KEYWORDS: - Co-digestion, Anaerobic digester, Municipal Solid Waste, Sheep dung, and biogas

1. INTRODUCTION

Municipal solid waste (MSW) generation is significantly increasing in Indian urban areas and started creating enormous waste disposal problems in the recent past [APHA, 1989]. More than 90 percent of the municipal solid waste which generated in India is dumped in an unsatisfactory way, what creates environmental hazards to water, air and land [Rao, et al., 2004], which creates the need of MSW management development capability to minimize the production of these and able to reduce the environmental impact and its effect on the public health. Waste minimization and energy generation are the recent emerging concepts. The conventional energy resources are declining nowadays, hence a suitable alternate for conventional resources are being explored. Cities in Maharashtra typically produce municipal solid waste 0.4-0.5kg/person/day. Solid wastes can be used for production of biogas.

*Corresponding Author Email id: - **ersansme@gmail.com**

Biogas comprises of 68% methane, 31% carbon dioxide, 1% nitrogen, it also forms a combustible mixture in the range of 6% to 15% concentration in air. Anaerobic digestion is a known process to digest the organic rich MSW. Resource recycling and energy saving systems for processing organic solid waste in urban areas need to be established. The anaerobic digestion is an attractive option for energy generation from the putrescible fraction of MSW as well as it enhances the volume reduction concept [CPCB, 2004]. It has reduced environmental impact, especially with respect to the greenhouse effect and global warming.

Anaerobic digestion has considered to be a promising energy saving and recovery process for the treatment of organically rich MSW. Anaerobic digestion also been suggested as a substitute method of removing the high concentration organic waste. Anaerobic digestion is a biological process wherein a diverse group of microorganism converts the complex organic matter into simple and stable end products in the absence of oxygen [Mufeed Sharholy, et al., 2008]. This process is very attractive because it yields biogas, a mixture of methane and carbon dioxide, which can be used as renewable energy resources. Several research groups have developed anaerobic digestion processes using organic substrates with different inoculums [Ajaya kumar Varma; online; Metcalf & Eddy, 2008]. In this view, anaerobic digestion of solid waste is a process that is rapidly developing a concept to cater the needs in solving the environmental issues. The characteristics of the biogas produced depends upon the nature and type of the substrate or feed stocks (wastes) used.

Anaerobic digestion technology has tremendous application in the future for sustainable development of both environment and agriculture because it represents a feasible and effective waste-stabilization method to convert the organic solid bio- waste into renewable energy with nutrient rich organic fertilizer. However, the application of this process is limitedly practiced especially in developing countries due to the lack of appropriate treatment system configurations and mainly due to the longer time required for the bio stabilization of waste.

Several studies have been made on the bioconversion of biomass by different researchers, for example Mata-Alvarez et al., 1992 carried out experiments on Barcelona’s central food market organic wastes, Lane, 1984 and Prema Viswanath et al., 1992 on fruit and vegetable wastes, Krishna N et al.,1991 on canteen wastes, Ranade et al., 1987 on market waste. Webb and Hawkes, 1985 have studied the gas yield–organic loading relationships for anaerobic digestion of poultry litter. Rao et al., 2000 have studied the ultimate bioenergy production potential of municipal garbage in batch reactors. There are a large number of factors which

*Corresponding Author Email id: - **ersansme@gmail.com**

affect biogas production efficiency such as environmental conditions like pH, temperature, type and quality of substrate, mixing Molnar and Bartha, 1989 process inhibitory parameters like high organic loading, formation of high volatile fatty acids, inadequate alkalinity etc.

This paper deals with the experimental study carried out by means of laboratory scale plant to generate biogas from the Market Waste. The objective of this study was to obtain the optimal conditions for biogas production from anaerobic digestion of organic rich municipal solid waste (MSW) using sheep dung as innoculum. The substrates were treated anaerobically for biogas production and pH was monitored. The study of these parameters will help us to establish a biogas system with available substrate and utilize different types of available organic waste for biogas production.

2. MATERIAL AND METHODS

The experiments were carried on batch Scale laboratory Digester (acrylic bottle) with total capacity of 20 L. The digester was made of acrylic sheet with bottom sampling outlet. The bottles were closed by rubber stoppers equipped with glass tubes for gas removal and for adjusting the pH. The effective volume of the reactor was maintained at 13L. Biogas production from the digesters was monitored daily by the water displacement method. The volume of water displaced from the bottle was equivalent to the volume of gas generated. The digesters were operated at room temperature.

2.1 Substrate preparation

Fresh organic MSW from vegetable market were used as feed to the bio reactor. The organic MSW consist of fruit waste and vegetable waste from the nearby vegetable market. The wastes were sorted and shredded, then mixed several times in laboratory and kept at 4°C until used. All reactors were loaded with raw feed stock and inoculated with sheep dung each separately. Water was added to obtain the desired total solid concentration.

2.2 Innoculum

The study had been carried out with sheep dung as inoculum, co digested the municipal solid waste from vegetable market with sheep dung. The percentage of inoculum for fermentation of the organic wastes from market is approximately 10%, 20% and 30% of the working volume (Weight) of substrate. The inoculum was collected and kept at 4°C until used, which contains all the required microbes essential for anaerobic digestion process.

2.3 Experimental procedure

*Corresponding Author Email id: - **ersansme@gmail.com**

The study is programmed to evaluate the mesophilic digestion of MSW at three different initial inoculums concentrations (D_1, D_2, D_3) and one control (D_o) without inoculum. The substrate concentration was expressed as weight of solids/total volume of solids plus water, assuming that the density of the solids is approximately equal to the density of water. Four digesters were operated at a volume of 20L and 13L (10kg) effective volume at continuous condition with different inoculums concentrations of 10%, 20% and 30% of weight solids respectively. All the digesters were fed with market waste, tap water and sheep dung (inoculum), used as the starter in the reactors. Liquid samples were drawn from each digetsers periodically and analyzed for pH, volatile fatty acids, alkalinity chemical oxygen demand and ammonia nitrogen. The pH was measured on an interval of every 2 days and it was maintained in the range of 6.8 to 7.3 using the 4M-Sodium Hydroxide solution as which is the optimum range for methanogens growth. Daily biogas generation was measured by water displacement method. The substrate was mixed once every day, at the time of the gas measurement, to maintain intimate contact between the substrate and the microorganisms. All the manipulations were conducted under sterile conditions and experiments were carried out in triplicate gas measurement, to maintain intimate contact between the microorganisms and the substrate.

The parameters analysed for the characterization of substrates were as follows: Total Solids (TS), Volatile Solids (VS), pH, Volatile fatty acid (VFA), Total Organic Carbon (TOC). Following quantities were monitored during the digestion process: pH, VFA, alkalinity, Ammonia nitrogen (NH3-N), COD and production of biogas. All analytical determinations and gas production were estimated according to the procedures recommended in the Standard methods for examination of water and wastewater. Gas production was measured at a fixed time each day by the water displacement method, with water prepared as specified in standard methods (APHA, 1989).

Gas samples were collected by gas sampling injectors and a sample of 100lit was used for each run. The biogas composition (CH4+CO2) was determined using a Gas Chromatograph (Chemito GC model 7610) equipped with a thermal conductivity detector and stainless steel column of length 6 ft, OD 1/4 in., ID 2 mm, Porapak Q 100 having mesh range 80–100. The carrier gas used was H2 and the analysis was carried out at a carrier gas flow rate of 30 ml/min with the injector, column and detector temperatures maintained at 120, 90 and 120 respectively. The gas quality was checked once a week.

*Corresponding Author Email id: - **ersansme@gmail.com**

Figure 1 Batch Reactor with Gas Collection System

3. RESULTS AND DISCUSSION

3.1 Substrate characteristics and Inoculums characteristics

The characteristic of the substrate and innoculum were shown in the Table 1 and 2. The digester was run for a period of 50 days. Degradation of substrate started steadily in the digesters; it took about 5- 6 days for the initiation of biogas production.

Table 1 Characteristics of Substrate – Vegetable Market

***Corresponding Author Email id: - ersansme@gmail.com**

Waste

S.No.	Parameters	Value/weight fraction (%)
1.	Moisture (%)	80.5
2.	pH	5.13
3.	Total solids (%)	19.5
4.	Total volatile solids (%)*	90.3
5.	Ash content (%)*	12.55
6.	Total organic carbon (%)*	20.35
7.	Total nitrogen (%)*	1.03
8.	Chemical oxygen demand (ppm)	3952

Table 2 Characteristics of Sheep Manure

S.No.	Parameters	Values
1.	pH	7.7
2.	Total solids mg/l	500
3.	Chemical oxygen demand mg/l	933
4.	Total nitrogen (%)	1.225
5.	Total organic carbon (%)	209.4
6.	Ash content (%)	9.2
7.	Total volatile solids (%)	78

3.2 Optimization of Biogas Production

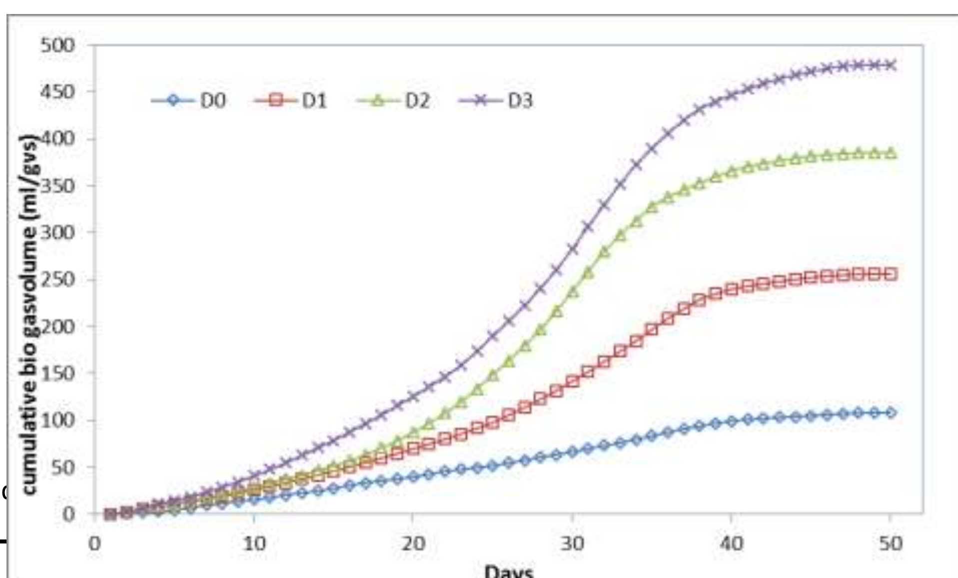
To study the effect of inoculum concentration on the performance of the anaerobic digestion process of vegetable market waste as substrate with initial sheep dung inoculum sludge concentrations of 0%, 10%, 20% & 30% (D_o, D_1, D_2 & D_3) of the weight of substrate.. The TS content was presented in term of dry matter and the cumulative biogas maintained at room ambient temperature along. The research was carried out in triplication. The data obtained from the study are then averaged and the cumulative volume of biogas

*Corresponding Author Email id: - **ersansme@gmail.com**

generation was observed for a period of 50 days and the results were shown in the Table 2. The digestion was characterized without fluctuation of biogas production at the beginning. Degradation of substrate started almost immediately and proceeded without problems in all digesters and biogas production is significantly increased due to exponential growth of microorganisms and to their higher adaptation to the change of the concentration of inoculum. Figure 2 indicates the cumulative biogas production for 4 digesters (D_o, D_1, D_2 & D_3). The biogas generation was low in the beginning, which was due to the log phase. After 22 days of observation, generation of biogas in all the samples tends to increase and this is due to exponential growth of microorganism's stationary phase of microbial growth.

Table 2 Productivity Profile and Composition of Gas from Vegetable Market Waste Biomethanation

Digester	Digestion period (Days)	Initial solids in the feed MSW (%)	Inoculum (%) Sheep dung	Working Volume of the digester(L)	Average Daily gas generation (L)	Gas Productivity $m^3/day/m^3$ working volume of digester	Methane (%)	Carbone dioxide
Do	50	100	0	14	0.980	0.07	50-60	40-50
D1	50	90	10	14	3.178	0.227	63-70	30-36
D2	50	80	20	14	5.376	0.384	68-73	27-32
D3	50	70	30	14	5.922	0.423	71-76	24-29



*Correspond

Figure 2 Cumulative Gas Generations with Sheep Dung

The rates of biogas generation differed appreciably according to the TS concentration. Furthermore, as shown in Figure 2, the maximum cumulative biogas generation obtained for D_0 was 108.45ml/gVS in 50^{th} day. At the end of the 50 days total cumulative biogas for D_1, D_2 and D_3 was obtained as 256.45ml/gVS, 385.65ml/gVS and 478.9ml/gVS respectively. The lower biogas yield indicated that there was an inhibition of methanogenic bacteria. The daily biogas yield, biogas generated per gram organic solids (volatile solids) for different concentrations of inoculum over a 50 days digestion time at room temperature (32°C) is shown in Figure 3. It can be observed from Figure 3, that the bulk of substrate degradation takes place up to a period of 22-37 days suggesting that the digesters should preferably be run at a digestion time close to 50 days for optimum energy yield. The maximum daily biogas yield obtained from the digesters D_0, D_1, D_2 and D_3 was in the range of 8.1, 14.4, 21.4 and 24.1 ml/gvs. Based on the results digester (D3) produced high value of energy from Market waste.

The profile of pH over the length of the digestion period at inoculum concentration 30% (D_3) under room temperatures is shown in Figure 4. The results indicated that the pH values seemed to vary with operation time in a similar way in all samples; as seen, the pH started from the same initial pH (6.9 –7.0), and in the all samples it dropped from 6.8 to 6.5. Dropped at first few days, partly due to the heterogeneity particles, subsequent hydrolysis processes occurred in the reactors and the volatile fatty acids (VFA) accumulation, especially during the first three days. However, all the pH increased after 7 days operations, and reached around 6.9 to 7.3, and then gradually increased; finally, it reached a level about 7.3. The pH varied between 6.8 and 7.4 which nearly lie in the favorable pH range of 6.5 to 7.4 for methanogenic bacteria.

***Corresponding Author Email id: - ersansme@gmail.com**

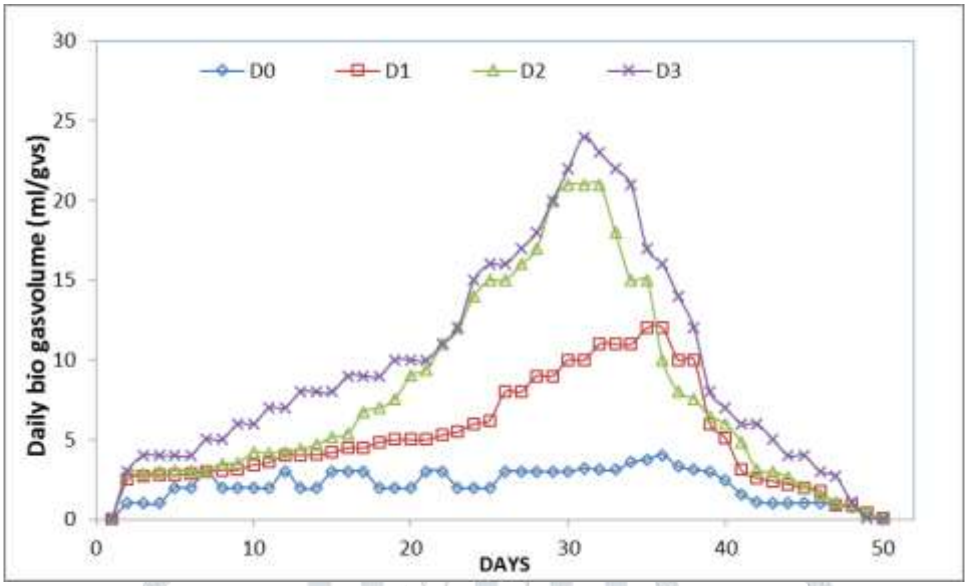


Figure 3 Daily Gas Generations with Sheep Dung

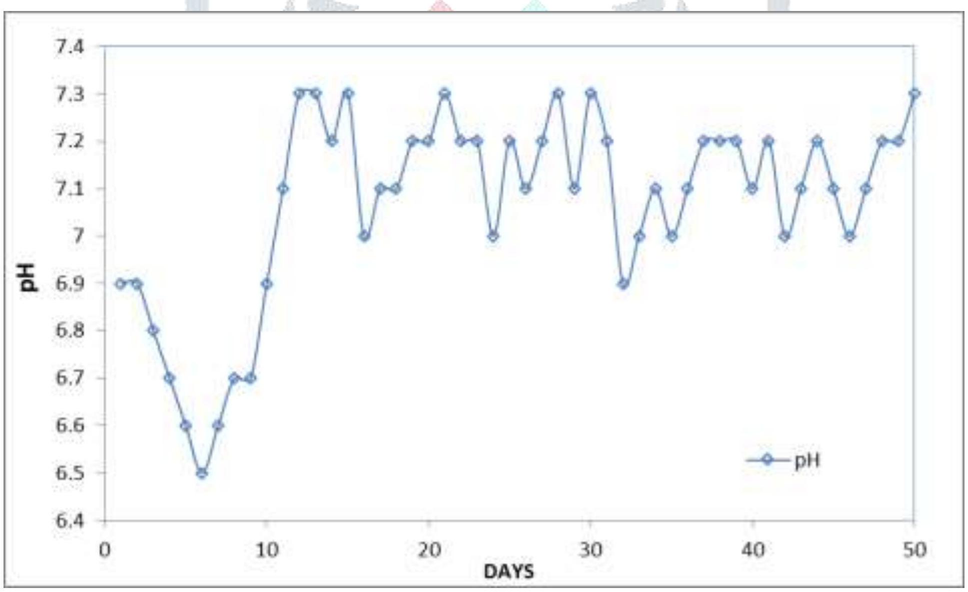


Figure 4 Variation of pH for Sheep Dung Co-digestion

*Corresponding Author Email id: - **ersansme@gmail.com**

A decrease in pH was observed during the first few days of digestion due to the high volatile fatty acids formation; hence the pH was adjusted to 7 using 4M-NaOH solution. The methane production occurs at pH (6.9 - 7.4) with a maximum value of 478.9ml/gVS as shown in Figures 4. The methane content of the biogas generated from the digesters was in the range of 50–56% during the first 2–4 days of the digestion and remained in the range of 60–74% for the remaining period. The Average CH4% in the digester was 55, 61.5, 70.5 and 73.5 for D_0, D_1, D_2 and D_3 respectively.

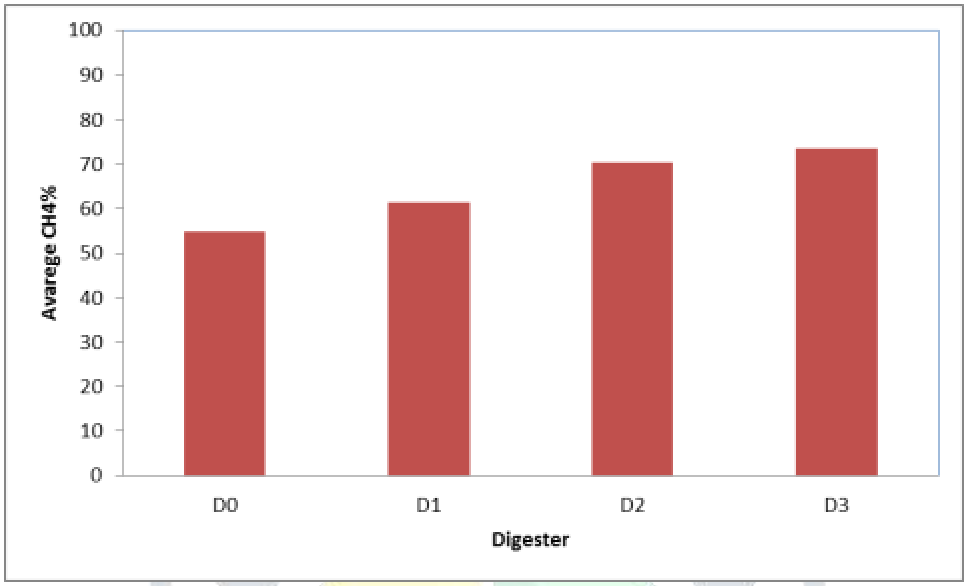


Figure 5 Percentage Methane Content in Digesters (D_o, D_1, D_2 & D_3)

4. CONCLUSIONS

In today's energy demanding lifestyle, Organic Municipal Solid Waste (OMSW) proves to be a renewable source of energy in the form of biogas. Anaerobic digestion of organic rich MSW with sheep dung anaerobic digesters increased the cumulative biogas generation considerably. After studying the various parameters of the varying inoculum concentration Co digested with substrates of the vegetable market municipal waste it was observed that the methane generation was lower in D_o. The study revealed that the gas generation directly proportional to the inoculum concentration and initial characteristics of the substrates. Biogas generation from vegetable market municipal wastes could be enhanced by adopting biotechnological applications. And further study could be carried by various pre-treatments of the above substrates to gain maximum methane percentage. At the end of the 50 days digestion about 478.9ml/gVS biogas was generated. The measured volume of biogas yield from the reactors co-digested using Sheep dung as inoculum were 256.45ml/gVS, 385.65ml/gVS and 478.9ml/gVS. The biogas generation was 0.227, 0.384 and 0.423 m3/day/m3 of digester volume

*Corresponding Author Email id: - **ersansme@gmail.com**

with the sheep dung innoculum variation of 10%, 20% and 30% respectively. It was observed that the methane content of the biogas generated from the digesters was in the range of 50–56% in control digester and that for digesters D_1, D_2 & D_3 were 63-70%, 68-73% and 61-76% respectively.

REFERENCES

1. Ajaya kumar Varma. R, Technology options for treatment of municipal solid waste with special reference to kerala, Available online;http:/www.sanitation.kerala.gov.in/pdf/workshop/techno2.pdf
2. APHA, 1989, Standard Methods for the Examination of Water and Wastewater, 17th ed., Washington, DC
3. Central Pollution Control Board (CPCB), 2004, Management of Municipal Solid Waste, Ministry of Environment and Forests, New Delhi, India
4. Krishna Nand, Sumithra Devi, S., Prema Viswanath, S., Somayaji Deepak, Sarada, R., 1991, Anaerobic digestion of canteen wastes for biogas production: process optimisation. Process Biochemistry 26, 1–5.
5. Lane, G., 1984, Laboratory scale anaerobic digestion of fruit and vegetable solid waste. Biomass 5, 245–259.
6. Mata-Alvarez, J. Mtz-Viturtia, A., Llabres-Luengo, P., Cecchi, F., 1993, Kinetic and performance study of a batch two-phase anaerobic digestion of fruit and vegetable wastes. Biomass and Bioenergy 5 (6), 481–488.
7. Mata-Alvarez, J., Llabres, P., Cecchi, F., Pavan, P., 1992, Anaerobic digestion of the Barcelona central food market organic wastes: experimental study. Bioresource Technology 39, 39–48.
8. Metcalf & Eddy, Inc., 2003, Wastewater engineering: Treatment and reuse, McGraw-Hill, New York
9. Molnar, L., Bartha, I., 1989, Factors influencing solid-state anaerobic digestion, Biological wastes 28, 15–24.
10. MufeedSharholy, Kafeel Ahmad, GauharMahmood, 2008, Municipal solid waste management in Indian cities – A review,Waste Management 28, 459–467
11. Prema Viswanath, S., Sumithra Devi, S., Krishna Nand, 1992, Anaerobic digestion of fruit and vegetable processing wastes for biogas production. Bioresource Technology 40, 43–48
12. Ranade, D.R., Yeole, T.Y., Godbole, S.H., 1987, Production of biogas from market waste. Biomass 13, 147–153.
13. Rao M. S. and S. P. Singh, 2004, "Bioenergy conversion studies of organic fraction of MSW: kinetic studies and gas yield–organic loading relationships for process optimization", BioresourceTechnol., vol. 95, pp.173-185
14. Rao, M.S., Singh, S.P., 2004, Bioenergy conversion studies of organic fraction of MSW: kinetic studies and gas yield-organic loading relationships for process optimization. Bioresour. Technol., 95, 173–185.

*Corresponding Author Email id: - **ersansme@gmail.com**

15. Rao, M.S., Singh, S.P., Singh, A.K., Sodha, M.S., 2000, Bioenergy conversion studies of the organic fraction of MSW: assessment of ultimate bioenergy production potential of municipal garbage. Applied Energy 66, 75–87.
16. Webb, A.R., Hawkes, F.R., 1985, Laboratory scale anaerobic digestion of poultry litter: gas yield–loading rate relationships. Agricultural wastes 13, 31–49 .

*Corresponding Author Email id: - **ersansme@gmail.com**