Research Journal of Engineering Sciences E- ISSN 2278 – 9472
Vol. **5(6),** 5-9, June **(2016)** *Res. J. Engineering Sci.*

Anaerobic Co-Digestion of Food Waste and Straw for Methane Production

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Available online at: www.isca.in, www.isca.me
Received 17th April 2016, revised 16th May 2016, accepted 4th June 2016

Abstract

Solid waste management programmes are driven by a desire to keep environment clean in the hope of promoting environmental quality and public health. Large quantity of food waste produced results in nuisance and cause foul smell due to their nature. These wastes are disposed off by dumping, thermo chemical process, sanitary landfill, composting. The biodegradable organic waste was carried out in anaerobic digestion in enclosed space under controlled conditions of temperature, moisture, pH, etc. Co-digestion of food wastes and straw is the best suited process, apart from biogas production, the methane fermentation process produces stabilized waste. Codigestion is combined digestion with different waste carried out in a single reactor. The present study focus on the Anaerobic digestion of mixed food and straw waste carried out in laboratory scale at ambient temperature condition and investigates on volume of biogas produced per unit weight of waste . Daily and cumulative gas produced was measured by water displacement method. Analysis of variability of feedstock during the digestion process was carried out .Samples showed considerable reduction in total solids, total volatile solids and COD during degradation process indicating the waste stabilization.

Keywords: Codigestion, Anaerobic digestion, biodegradability, Food waste and Straw.

Introduction

Majority of the organic fraction of Municipal Solid Waste (MSW) accounts for food waste. Large part of organic wastes produced in the markets is the food waste. Food waste from cafeterias, restaurants and residential are continuously increasing due to the improved standard of living and increasing population. Most of the food waste has not reached necessary stabililization and are disposed in landfill or dumping sites may cause environmental problems[1].

Effective utilization of this waste for biogas production could be the best solution which could be utilized in surrounding areas and the digested waste as fertilizer. These wastes can be treated in biological treatment like anaerobic digestion than other techniques like incineration and composting due to the high organic and moisture content[2]. There have been a number of reports on the utilization of food waste individual or mixed as feedstock for biogas production.

Biogas production from anaerobic digestion: Waste containing moisture above 50% is best suited for bioconversion processes than the thermo- conversion processes[3]. Food waste due to high biodegradability, organic and moisture content seemed to be a good source for biogas production through anaerobic digestion process. Anaerobic digestion is a process in which biodegradable materials are broken down by microorganism in the absence of oxygen. There are four key biological and chemical stages of anaerobic digestion: Hydrolysis, acidogenesis, acetogenesis and methano-genesis. Rapid acidification and the larger production of Volatile Fatty Acids (VFA), are the major limitation of food waste which reduces the methanogenic activity of the digester. Co-digestion of FW with other organic wastes are more popular. The main advantages of co-digestion are: increasing the biogas production yield, cost sharing and effective utilization of equipments[4].

Biomethanation option: The process involves the conversion of biomass to methane under anaerobic conditions is known as biomethanation. Biomethanation of food wastes and straw is the best suited process as it not only enables biogas production but also the methane fermentation process producing stabilized waste[5]. Methane rich biogas can replace fossil fuels in energy production. The objective of this paper is to: i. study the biomethanation of food waste matter in co-digestion process under ambient temperature condition in laboratory scale ii. To investigate the biogas yield and to analyze the variability of the feedstock during the digestion process.

Materials and Methods

Substrate: Food waste was collected from a hotel in Coimbatore, which contains leftovers of cooked foods such as bread, tomatos, rice, cucumber, pumpkin, beans, cabbage. Hand sorting was done to segregate unwanted materials including paper, plastic covers, packaging materials etc. The wastes were ground to pulp with the help of kitchen blender. Straw was collected, sun dried and crushed to various particle size. After being shredded to small size, straw and FW are kept at 4°C until used.

Alkali pre-treatment: In order to remove the lignin content from straw alkali pre-treatment is done with sodium hydroxide, lime or ammonia. This process helps to make part of cellulose accessible to enzymes. NaOH is found to increases the bioenergy production by 16.6%. Furthermore, Volatile Solids (VS) removal by 40%-90% is achieved when the sludge is treated with dilute NaOH at room temperature (25-35°C).

Inoculum: Inoculum was used as the waste deficit anaerobic bacteria for digestion process. The inoculum used was goat rumen mixed with cow dung slurry amounting to 50% of bioreactor working volume and mixed with the wastes and the reactor was closed. It was added to reactor to initiate digestion. The resultant mixture was used as the feedstock in the batch reactor for anaerobic digestion process. Chemical analysis of feedstock was performed using standard methods.

Reactor set up: A batch reactor made of acrylic sheet material of capacity 25 L was used as anaerobic digester. The batch rector used was of square type with total height of 65 cm. A gravel layer of height 30-40 mm was provided at the bottom of the reactor that acts as a bed for the drainage collection. The reactor was provided with a sampling port to collect the digested sample for analysis. An outlet to collect the gas produced is also provided in the reactor. The gas outlet was connected to a gas collection jar of 2.5L capacity in which gas is passed through 5% NaOH solution. CO_2 produced will be absorbed by NaOH solution. The construction details of the lab scale batch reactor are given in Table-1.

Table-1
Details of batch reactor

Parameters	Specification
Reactor Type	Square
Length (cm) x Breadth (cm)	20x20
Height(cm)	65
Volume(L)	25

Experimental Procedure: The substrate was mixed with inoculum having a total volume of 15 L i.e. 60% of the bioreactor volume[5]. The top of the reactor was tightly closed to maintain the stringent anaerobic condition. The experiment was carried out at ambient temperature. The reactor was mixed by means of shaking once in a day. Gas production is measured by downward displacement of water as amount of water displaced is equal to the amount of biogas produced.

The changes in the characteristics of feedstock during digestion process are observed by collecting sample through sampling port once in 10 days. The feedstock collected during digestion process was analyzed for determining pH, total solids (TS), volatile solids (VS), chemical oxygen demand (COD), alkalinity detailed in standard methods.

Analytical methods: pH was measured using digital pH meter (ELICO-LI 120, India). The feedstock collected during digestion process was analyzed for determining pH, total solids (TS), volatile solids (VS), chemical oxygen demand (COD), alkalinity detailed in standard methods[6]. Moisture content and dry matter analysis were done according to the test procedures given in 'Soil and Solid waste analysis, A Laboratory Manual' by P K Behera[7]. Volatile Fatty Acids (VFA) were analyzed by titration procedure according to Kapp[8].

Table-2
Characteristics of feed stock

Parameters	Values
pH	6.8
Moisture content (%)	90.18
Dry matter (%)	9.8
Total solids (%)	11.65
Volatile solids (%)	87.94
Non volatile solids (%)	12.06
Alkalinity (mg/L as CaCO3)	3300
Chemical Oxygen Demand (mg/L)	11200

Results and Discussion

Characteristics of Food waste and Straw: One of the important step in anaerobic digestion process is waste analysis. The amount and the composition of the biogas produced calculated from the general composition of the substrate to the system. The moisture content of FW and straw was found to be 90.18% . The high moisture content shows FW and Straw is not suitable for incineration or land filling. The COD of the feedstock was found to be 11,200 mg/L. High COD value in the feedstock showed presence of high organic matter in the substrate. Total solids were found to be 11.65%.

Variability of the feedstock during the digestion process: The change in the characteristics of feedstock during digestion process is given in Table-3. The growth of the microorganism in anaerobic digestion process is affected by pH. The optimum pH for acidogenic bacteria is in 56.5, whereas 6.8 - 7.4 is the optimum range for methanogenesis bacteria[1]. The feedstock was fed with a pH of 6.8. During the digestion process, a decrease in the value of pH of about 5.5 was observed from the first four weeks (30th day). The decrease in the pH reveals that the digestor is in the acidic phase.

The pH drop inhibits the initiation of methane fermentation process and hence the generation of gas. To keep the pH in the optimum range for the survival of methanogens, 5M $NaHCO_3$ was added to the feedstock.

The TS in the feedstock was 11.65% and reduced to 4% at 100^{th} day. The removal efficiency is 65.67%. The TVS in the feedstock was 87.94% and reduced to 37.9%. The decrease in the values of volatile solids indicates that the organic matter was utilized by the microorganisms to produce biogas.

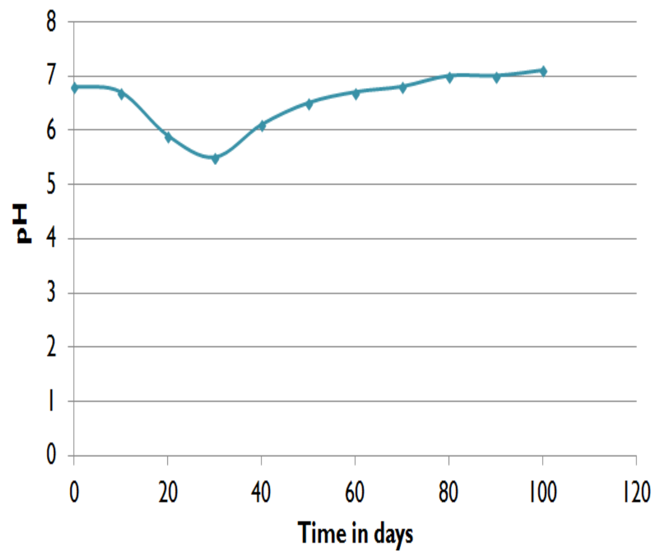

Figure-1
Variation of pH of feedstock with time

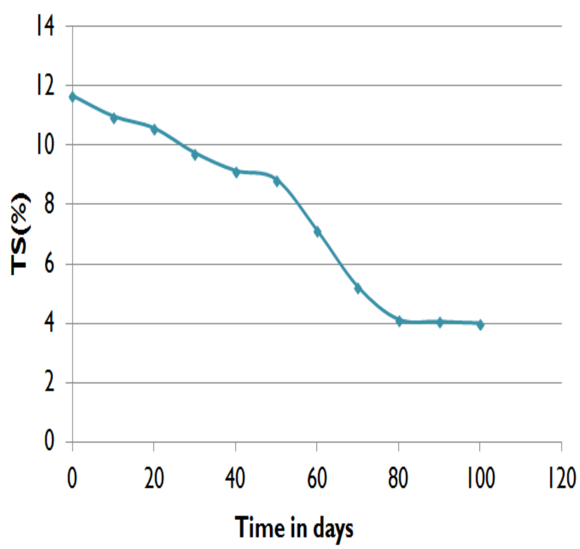

Figure-2
Variation of TS of feedstock with time

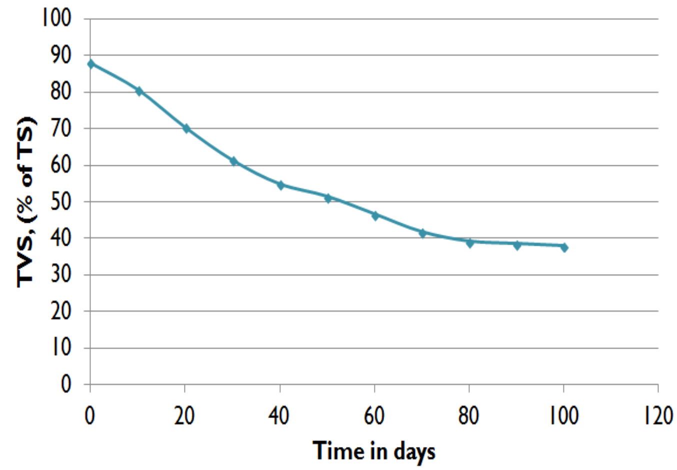

Figure-3
Variation of TVS of feedstock with time

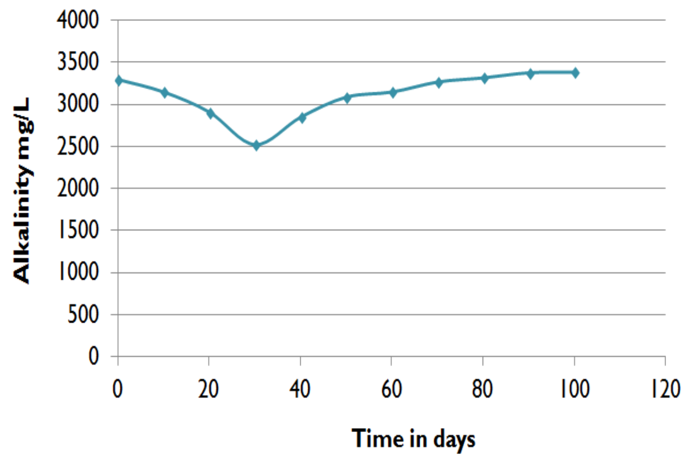

Figure-4
Variation of alkalinity of feedstock with time

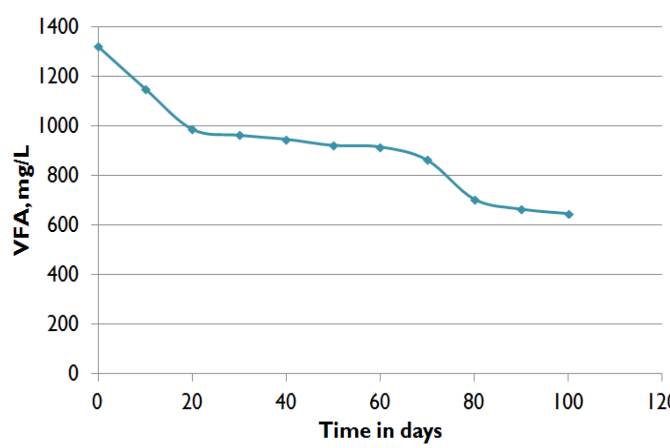

Figure-5
Variation of VFA with time

Table-3
Characteristics of feed stock during digestion process at different periods

Time (days)	pH	TS (%)	TVS (% of TS)	Alkalinity (mg/L)	COD (mg/L)	VFA (mg/L)
0	6.8	11.65	87.94	3300	11200	1320
10	6.7	10.96	80.66	3150	10600	1150
20	5.9	10.56	70.34	2910	9600	987
30	5.5	9.73	61.34	2521	9305	963
40	6.1	9.13	54.82	2850	9043	947
50	6.5	8.84	51.43	3090	8430	922
60	6.7	7.13	46.61	3150	7897	916
70	6.8	5.23	41.74	3270	7216	863
80	7	4.13	39.17	3320	6759	705
90	7.1	4.05	38.51	3380	5140	665
100	7.1	4	37.9	3389	4947	647

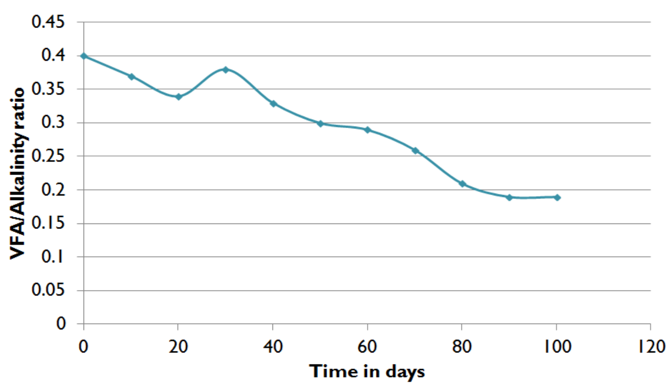

Figure-6
VFA/Alkalinity ratio in the reactor

Alkalinity is very essential parameter as it provides the required buffering capacity to anaerobic system. Alkalinity was found to vary proportionately with pH value. For the digestion to be stable alkalinity should be in the range of 2000-4000 mg $CaCO_3$ / L. Inhibition of methanogenic population by volatile solids is considered as the prime reason for reactor failure. The variation of VFAs produced by the reactor is shown in Figure-5. The stability of reactor is found using VFA/alkalinity ratio and should be less than 0.4. The ratio in the reactor during the study period ranged between 0.2 to 0.4. High COD value in the initial sample showed presence of high organic matter in the substrate. COD was found to decrease with time as depicted in the Figure-7. The COD value of the feedstock was 11,200mg/L and is now reduced to 4947 mg/L. The COD removal efficiency is found be 56%. The reduction in the COD value is due to the conversion of organic compounds in the substrate to generation of biogas.

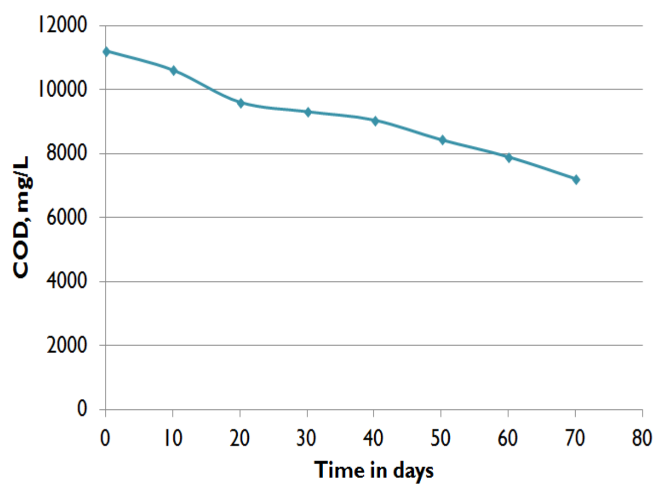

Figure-7
Variation of COD of feedstock with time

Cumulative gas generation: The biogas production was lowered during the acidogenic phase. After the addition of the buffer solution, the pH value was observed close to optimum range, gas production was found to increase after acidogenic phase. The total amount of gas produced is 3973 ml. The variation in the biogas yield is presented in Table-3.

Table-3
Cumulative gas generation with time

Time (days)	Cumulative gas production (in ml)
10	1020
20	1635
30	1910
40	2126
50	2353
60	2700
70	3240
80	3421
90	3789
100	3973

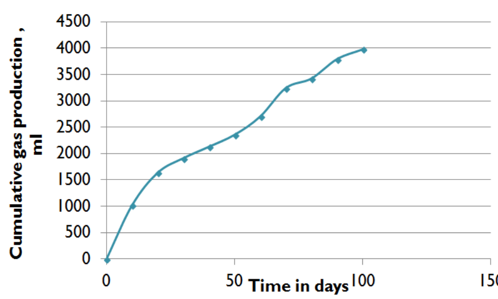

Figure-8
Variation of cumulative gas generation with time

Conclusion

The following are the general conclusions drawn from the study of biomethanation of food waste and straw. This can be utilized as a potential source for energy recovery by subjecting to anaerobic codigestion process. The biogas yield was found to be maximum during 13th week when the ph value was in the optimum range. Significant reduction was found in the characteristics of feedstock during the digestion process. Stabilized waste can be utilized as organic manure for plants.

Acknowledgment

The authors gratefully acknowledge Coimbatore Institute of Technology, Coimbatore for providing the Laboratory facilities, HOD and Faculty of Environmental Engineering & Management and Civil Engineering, CIT, Coimbatore for the Technical support.

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