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Anaerobic Co-Digestion Of Cafeteria Wastes And Cow Dung Mixtures For Biogas Production

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Abstract: *Biogas production is one of the most important tools that can be used to alleviate the problems of global warming, energy security and waste management. Eritrea has plentiful of biomass, cafeteria and agricultural wastes as raw materials for the effective biogas production to overcome ever the energy demand. This paper is mainly illustrated in finding the optimum conditions for biogas production with the help of cow dung and cafeteria wastes. Anaerobic single stage co-digestion of cafeteria wastes and cattle dung was analyzed in batch mode at mesophillic conditions for the effective biogas generation. A conversion of 75% of the organic solids fed into digester [HRT] was obtained for every single stage batch digestion at 40 days retention time. The average gas yield was high and it is 0.34*m^3*/kgVS added. To make favorable fermentation conditions, the content of the initial Total Solids [TS] was changed from 16% to 8% by diluting with water. Maximal overall methane productivity was attained when the ratio CD/CW was 50:50 and maximum organic loading rate was 3.55kgVS/*m^3*d found from semi-continuous digestion on 50:50 without clogging of the digester.*

Keywords: anaerobic co-digestion, cafeteria wastes [CW], cattle dung [CD], biogas, volatile solids [VS]

I. INTRODUCTION

Eritrea Institute of Technology [E.I.T] is one of the most reputed educational institutions in Eritrea, which plays vital role in producing more number of Science and Engineering graduates. E.I.T cafeteria wastes are getting accumulated everyday approximately 150kg and these wastes can be effectively used for biogas generation as well as bio-fertilizer production. Cafeteria wastes contain cooked-food wastes, cooked-vegetable wastes etc. Cow dung is also plentiful in nearby village. Therefore we have concentrated to do the experiments with the mixtures of cow dung and cafeteria wastes.

We have already done experiments in biogas generation from the various blending ratios of food wastes and cattle dung and we got the average gas yield was 0.290m^3 per kg VS added and the optimum ratio was found to be CD: BW=70:30.We were very much keen on doing experiments with our cafeteria wastes and cow dung mixtures mainly to make use of the wastes effectively. Hills and Nakano has highlighted the importance of feedstock mashing and homogenizing and they had shown that the highest gas production occurred with smallest particle size. Therefore we used a small crusher for preparing the cafeteria wastes into small size to do a preliminary experiment and we got less clogging the reactor on appreciable organic loading. Moreover we found that the stable gas production is also obtained. M.Saev, B.Koumanova and Iv.Simeonov worked in anaerobic co-digestion of wasted tomatoes and cattle dung for biogas production in semi-continuous mode. They had shown that a conversion of 72.5% of the organic solids fed into the digester at 20 days hydraulic retention days was obtained. The average gas yield was 220dm^3per Kg VS added. They used 7%total initial solids and later diluted to 3.5% to avoid clogging.

In this study, our objective is to find optimum condition in a single stage wet co-digestion of a mixture of cafeteria wastes and cattle dung at mesophillic conditions in batch mode to find out the optimum ratio and then by making use of the same optimum ratio in semi continuous mode to find out the optimum organic loading during which no clogging of the digester. In large scale, we have a plan of constructing a digester which would be operated in semi continuous mode. Biogas has a promising potential in Eritrea. This paper has been focussed and monitored the optimum conditions for the biogas production.

II. EXPERIMENTAL WORK

a) Substrates Homogenization and Maintenance

Organic components in cafeteria wastes [expressed as COD] are generally easily biodegradable and mainly consist of carbohydrates, proteins, fats. This is illustrated by the relatively high BOD/COD ratio of 0.75. The cafeteria wastes mainly consist of food and vegetable wastes etc. The cafeteria wastes were collected from the E.I.T. cafeteria and the cow dung were collected from the nearby village. Both wastes were crushed separately into small particle sizes of 2mm and were adjusted to 8% [mass]by diluting with water. Both the materials were stored at 0°C in a refrigerator before usage. Both substrates were mixed at a pre-determined ratio before feeding into the batch reactor.

b) Digestion Process

Insoluble organics are first converted into soluble organics by the extra cellular enzymes secreted by hydrolytic bacteria and then the soluble organics are converted into acids by acid forming bacteria. Finally methanogenic bacteria [strict anaerobes] convert the acids into biogas.

c) Laboratory Set-Up

As shown in the figure I, the air-proof digester with working volume of 5lt was operated in batch mode and mesophilic conditions [35°C±0.5]. A crusher was used for homogenizing the feed materials. A gasholder was used to collect the biogas and the volume of biogas was continuously measured with water displacement techniques and the composition of biogas was also continuously monitored by chromatography. Initially the digesters were charged with cow dung slurry using an active culture as inoculums. Gentle stirring and mixing was given. After getting steady state biogas yield, we mixed the cafeteria wastes to investigate the biogas production in different batches. The results showed a rapid and stable process achieved by optimal increase of the cafeteria wastes and at the same time, clogging of the reactor is the reason for decrease in biogas for very high cafeteria waste addition. We used digesters with operating volume of 5liters fed with 3.5gVS per liter as an average value and retention time of 40days.

III. ANALYTICAL METHODS AND THEIR DETERMINATION

We monitored temperature, pressure, retention time and volume during digestion. The volume of total gas production was measured by the substitution of water volume in gas holder cylinder. Gas production was measured daily.

The quality of the biogas was tested periodically by gas chromatography for methane and carbon dioxide content. The following parameters were regularly measured using standard methods during the experimentation.

Measurement of Total solids [TS] and Volatile solids [VS] were according to the method described by Arnold and Panswad.

Measurement of Chemical oxygen demand [COD] was done by Dichromate reflux method. Volatile fatty acids [VFA] concentration was measured by Wissuttisak. Contents of feed such as proteins, carbohydrates, fats etc were measured initially.

IV. RESULTS AND DISCUSSION

The average composition of the cafeteria wastes is presented in table 1.

Table-1: Average composition of the cafeteria wastes

Parameters	CW	CD
TS[%]	8	8
VS[%]	95	836100
COD [mg/lt]	6500-8600	6100
BOD[mg/lt]	3000-6000	4290
N in mg/lt	46-60	30-38
P in mg/lt	35-40	10
pH	6.8	7.3

Table 2: Average biogas composition on steady state biogas yield in batch process

Ratios CD:CW	CH_4%	CO_2%	Average VFA concentration during start of the experiment	Average VFA concentration during end of the experiment
90:10	66.0	29.5	3	1.9
80:20	68.0	30.0	3.3	1.6
70:30	68.5	29.5	3.7	1.4
60:40	69.0	29.0	3.4	1.7
50:50	70.8	27.5	3.8	1.8
40:60	63.2	32.9	2.9	2.0
20:80	59.6	33.0	2.7	2.1

Table-3: Comparison of the experimental data obtained with different mixtures of CD and CW [HRT 40 Days]

Ratio of feed content	TS%	Biogas production, lt/lt day	Biogas yield, $m^3/kg\ VS_{added}$	Methane yield, $m^3CH_4/kg\ VS_{added}$
CD	8	0.41	0.17	0.099
CD:CW 90:10	8	0.48	0.22	0.13
CD:CW 80:20	8	0.57	0.26	0.15
CD:CW 70:30	8	0.61	0.36	0.16
CD:CW 60:40	8	0.68	0.36	0.2
CD:CW 50:50	8	0.94	0.46	0.3
CD:CW 40:60	8	0.72	0.29	0.17
CD:CW 20:80	8	0.42	0.25	0.16

V. CHANGE OF PARAMETERS DURING FERMENTATION

Higher values of VS, COD and the value of C/N ratio as 18.5 are favorable for anaerobic digestion. Because of the neutral pH conditions on mixing, there is a need of neutralization rarely on digestion process. The experiments were carried out with batch process of the cafeteria wastes and the cattle dung on different ratios. Initially the reactor was filled with CD only and it was left to reach a steady-state biogas yield. The average biogas production was 0.45lt/ltday. After the start-up has been achieved, a co-digestion was started with a feed of CD and BW. Different ratios of cow dung and cafeteria wastes were taken in different digesters as follows.
Cow dung: cafeteria wastes=90:10,80:20,70:30,60:40,50:50,40:60,10:90

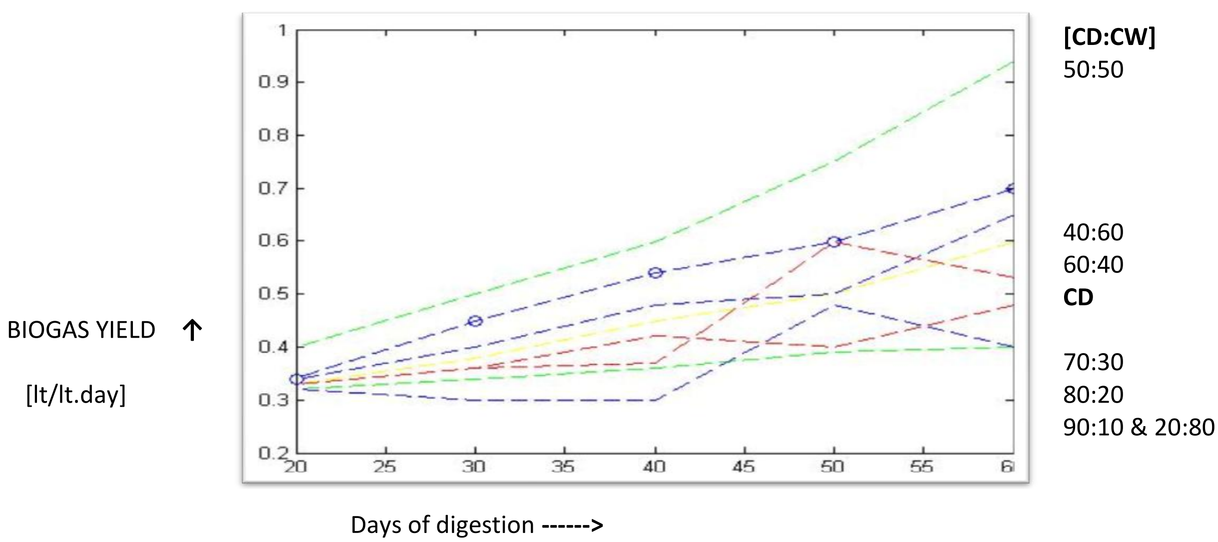

Figure-2: Production of Biogas during the Process [BIOGAS YIELD IN [lt/lt.day] Vs days of digestion]

As shown in fig.2 the biogas production increased to a higher value after CW addition with 50:50 ratio. The average biogas composition was 70.8% CH_4 and 27.5%CO_2 [Table.2]. During the process the concentration of VFA in the soluble fraction indicated an increase from the initial average value of 0.5g/lt to the average value of 3.8g/lt on the digestion start and then a gradual decrease in concentration of VFA was obtained [Table 2].

On continuous monitoring, we observed that there was no significant decrease in pH in the reactor and it ranged within the neutral value. No additional dilution has been done during proceeding of the experiments. The VS and COD transformed into biogas was 75% and 55% respectively. After 10 days from the beginning of the process the composition ratio was changed to the different ratios in different digesters. As shown in Fig.2 it is clear that the biogas production increased with increase of CW in the influent and the maximum value was 0.94lt/lt.day for the ratio 50:50. Because of the slow adaptation of the microorganisms to the new substrate, digestion was characterized with fluctuations of biogas production at the beginning.

Table-4: Characteristic changes of the materials due to biodegradation.

CD:CW	TS_{in},%	TS_{eff}., %	Extent of biodegradation of TS%	VS_{eff}., %	CODin., g/lt	CODeff., g/lt	Extent of biodegradation of COD, %
90:10	8	3.0	62.5	69	109	81	37
80:20	8	2.9	63.8	60	94	56	40
70:30	8	2.7	66.3	59	86	50	42
60:40	8	2.7	66.3	57	82	47	43
50:50	8	2.6	67.5	53	80	43	46
40:60	8	3.7	53.8	63	72	57	21
20:80	8	4.7	41.3	76	69	55	20

The above experiments were carried out without any further dilution. Some ratios were not given appreciable biogas production rate due to the clogging of the batch digester. As can be seen from Fig.2 the biogas production decreased slowly for the two ratios. Methane content and production was stable and appreciable on 50:50 ratios.

VI.SEMI CONTINOUS DIGESTION ON OPTIMUM RATIO [50:50]

Another experiment was also conducted to find the optimum organic loading rate in a semi-continuous digester specifically for the optimum feed ratio of 50:50. Practically it was found that the maximum organic loading rate of 3.55kgVS/m^3 day would not be causing any clogging of the digester.

On decrease of the organic loading rate as 1.5 kgVS /m^3day, the biogas production decreased slowly.

VII. CONCLUSION

It was clearly observed that a stable anaerobic co-digestion can be achieved using a mixture of cafeteria wastes and cattle dung in various proportions. The addition of CW increased the biogas yield from 0.41lt/lt.day to 0.94lt/lt.day at [50:50] ratio. It was found that CD: CW of 50:50 is the optimum ratio from batch process. Moreover it was found that there was no clogging of the reactor on the maximum organic loading rate on 3.55kgVS/m^3.day in semi-continuous mode on 50:50 optimum ratios.

The gradual reduction of the VFA concentration clearly indicated the stability of the process. Thus more profitable biogas production is achievable at lower production cost. Moreover, it is very clear that the partially digested wastes can be effectively used as bio-fertilizers in the farms of the nearby village. E.I.T as an institute is going to put up a biogas plant which can be used as a study plant for the nation, this will surely facilitate in promoting biogas technology. The final observation of this work clearly indicates that cafeteria wastes can be effectively used for the production of biogas using cow dung as a starter and continuous production of biogas is also possible with cafeteria wastes .

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