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Anaerobic Co-digestion of Lignocellulosic Waste Co-Digested with Food Waste under Mesophillic Conditions

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Abstract—Lignocellulosic waste (LW) is difficult to degrade without pretreatment. Anaerobic Co-digestion helps in degradation of LW and hence enhancing the methane production. In the present study, the optimum conditions for maximum methane production with the help of LW and Food Waste (FW) has been determined. Biochemical Methane Potential (BMP) study has been conducted under mesophillic condition (37^0C) during summer season with different ratios of LW and FW, a control solution (inoculum) which is anaerobic sludge was used to enhance the microbial activities. The result indicates that, the co-digestion significantly effects the methane concentration in biogas. The methane production is increased about 93% in co-digestion of LW and FW in ratio 1:1.5 as compared to the mono-digestion of lignocellulosic waste.

Keywords: Lignocellulosic waste (LW), Anaerobic co-digestion, Biochemical Methane Potential (BMP)

1. INTRODUCTION

The energy need of rural areas in India is increasingly day by day and to meet this ever increasingly demand the most efficient and compatible method, anaerobic digestion is adopted. Anaerobic digestion has several advantages as an attractive method of waste treatment and energy production: low operational cost, energy production, pathogen control, and environment-friendly operations [1]. Anaerobic digestion consists of biochemical reactions in which biomass are decomposed into biogas and digested by the help of different microbial population through the biochemical metabolic pathways in an oxygen depleted environment. The process described in four phases Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis [2].In anaerobic digestion, initially, complex organic materials degrade into soluble monomers by hydrolysis and then followed by the acid-forming phase (Acidogenesis) in which formations of volatile fatty acids (VFAs) takes place. The next stage Acetogenesis takes place through carbohydrate fermentation and the result consists of acetate, CO_2, and H_2. The final stage, Methanogenesis is perhaps the most crucial step of anaerobic digestion in which it plays a vital role in the formation of methane-rich biogas. The methane rich Biogas generation represents the most significant advantage of AD over composting. About 70 to 80% of the energy content of the initial organic compounds is preserved in the methane, so growth in microbial biomass is lower for anaerobic digesting than aerobic, resulting in greater volume and biomass reduction [3]. Although anaerobic digestion can be considered to go through in these four stages, all the processes take place simultaneously and synergistically [2]. The ultimate product of anaerobic digestion is biogas and digestate. In the present scenario, anaerobic co-digestion treatment method which includes treatment of different wastes together emerges as an effective and systematic way to manage organic waste and production of renewable energy simultaneously. Anaerobic co-digestion of LW provides an excellent opportunity to convert abundant bioresources into renewable energy. Anaerobic Microorganisms were not able to digest LW due to their intrinsic ability to degrade substrate rich in cellulosic fiber. However, there are still several challenges that must be overcome for the efficient digestion of LW [4]. As food waste (FW) is a growing problem, and the disposal of it is controversial, causing increased food prices and the resources required. It can be utilized as a co-substrate for biogas production and enhance methane production.

Biochemical methane potential (BMP) is a study done for a period of 30 days having a neutral pH, ranging from 6.5 to 7.5, in which the known amount of substrate biodegrade under optimal anaerobic conditions in the laboratory. The BMP study is done in batch mode and in bench scale, measuring the maximum amount of CH_4 or biogas per gram volatile solids (VS) produced by a known quantity of substrate in anaerobic conditions. The result from the analysis shows the concentration of organics in a substrate that can be anaerobically converted to biogas [5]. Lignocellulosic is a complex formation of cellulose, hemicellulose, and lignin [6] with a smaller amount of proteins and extractives which is soluble non-structural materials such as non-structural sugars, nitrogenous material, and waxes. A lot studies were done to enhance the methane concentration of biogas. The co-digestion of cafeteria waste and cattle dung was analyzed in batch mode and it was reported that 75% of organic solids has retention time of 40 days. The average gas yield was 0.34 m^3/ Kg VS [7].To enhance the digestion of lignocellulic biomass the categorized pretreatment methods were mechanical, thermal, chemical, biological or combination of them. The benefits of pre-treating the biomass includes high biogas yield, reduction in digestate quantity, reduction in retention time, better energy balance and better economical feasibility [8]. As LW required pretreatment before going under digestion process. On the other side, FW having high carbon content and result in acid formation which inhibits the growth of methanogens and a biogas with less concentration of methane is produced [9]. The objective of the present study is aimed to find the optimum conditions for maximum methane concentration of biogas in different mixing ratios of LW and FW through co-digestion.

2. MATERIALS AND METHODOLOGY

This study mainly focused on the rural area of India. Sample characterization was done by prescribed method in CPHEEO Manual 2013. Collected organic solid waste was kept in a freezer at 4 °C for reducing degradation before use. Greater particle–substrate surface areas increase contact between micro-organisms and organic mass [10]. Thus, the microbes easily degrade the biomass and enhance the rate of degradation. Before BMP test, the substrate was analyzed and the parameter like moisture content (MC), total solids (TS), volatile solids (VS), ash content as well as carbohydrates, lignin, cellulose, and hemicellulose were find outas prescribed by the Bureau of Indian Standards (BIS No. 10158-1982).The BMP study was done on Serum bottles of 125 mL with working volume of 100 mL were used as anaerobic batch reactors. The known amount of substrate and inoculum was transferred to each serum bottles. Biogas production in each serum bottles was measured on daily basis. Blanks (i.e. only inoculum) were run parallel to these reactors (serum bottles) in all phases of the study. Biogas collected at room temperature was normalized to standard temperature and pressure (STP). All the set-up were kept on the triplicate basis. Average values were reported. The methane concentration or methane COD is reported after blank corrections. Based on substrate VS % of WW, the volume of inoculum was decided and filled into the serum bottles, and then the substrate was added, and then by adding the media, bottles were filled up to the working volume, and remaining space was left blank to fill nitrogen gas to make anaerobic conditions. The experiment was done in different ratios of samples as Control (Inoculum), LW, FW, LW:FW (1:0.5, 1:1, 1:1.5). All samples were carried out in triplicate. For maintaining the anaerobic conditions, Bottles were sealed with silicon and aluminum cap. Filled bottles were kept in an incubator at 37 °C. Total volume of biogas measured daily with the help of frictionless glass syringe. The gas produced in the head space of the serum bottles was extract using a 100µL gas tight syringe and was analyzed for methane composition by Gas Chromatography (Agilent Technologies 7890A series) equipped with a thermal conductivity detector (TCD) and packed with molecular sieve column (PORAPAK Q column) having dimension (6×0.12”×0.85”). The operational temperatures at the injection port, column, oven, and the detector were 75^0C, 60^0C, 220^0C and 200^0C respectively. H_2 was used as the carrier gas at a flow rate of 25 mL/min.

3. RESULTS

The physico-chemical characteristics such as Total Solids (TS), Volatile Solids (VS), Moisture Content (MC) and Ash Content were determined before the BMP study. The following observations were calculated and shown in Table 1. The comparative study is shown in figure 1.

Table 1: Physico-chemical characteristics of samples.

S.NO.	MC (%)	TS in % WW	VS in % WW	Ash in % WW
Inoculum	**95.65**	**4.3**	**2.80**	**0.16**
FW	**68.49**	**31.51**	**30.16**	**0.07**
LW	**34.53**	**65.47**	**50.50**	**0.76**

Inoculum has the highest moisture content of 95.65% while LW has the lowest moisture among the samples having a moisture content of 34.53. Total Solids and Volatile Solids has maximum Concentration in LW.

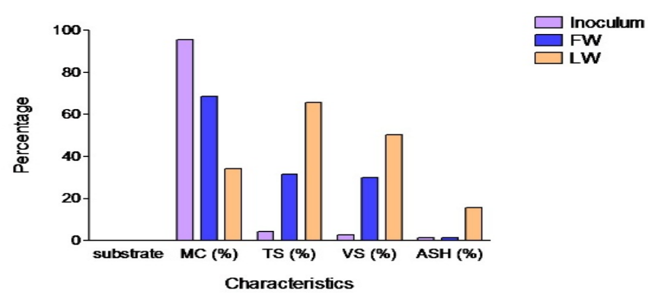


Figure 1: Comparative study of Physico-chemical Characteristics

BMP Data

The biogas and methane production for different ratios of samples were represented in Table 2. The highest biogas yields of 519.75 mL/g VS produced in FW while lowest of 61.67 mL/ g VS occurs in case of S T. Methane concentration is highest in case of optimum ratio of LW and FW i.e. (1:1.5T) of 50.70 %. The biogas production and methane concentration were shown in Figure 2 and Figure 4 respectively.

Table 2: Methane and Biogas production for different samples

Sample Code	Cumulative Biogas mL/g VS	Methane mL/g VS	Methane %
LW	40.40	14.20	35.14
1:0.5T	146.22	54.67	37.39
1:1T	247.93	110.49	44.57
1:1.5T	375.04	190.15	50.70
S T	56.97	16.00	28.09
FW	519.75	233.50	44.93

Figure 2: Biogas Production of different samples

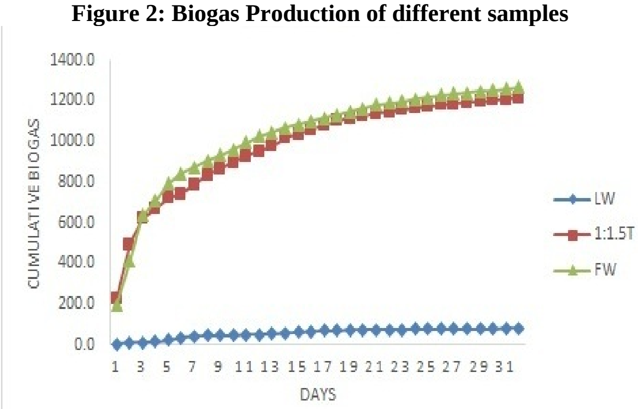


Figure 3: Biogas of Co-digested Samples

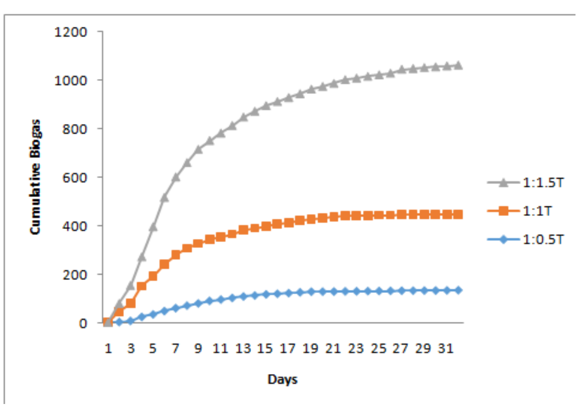
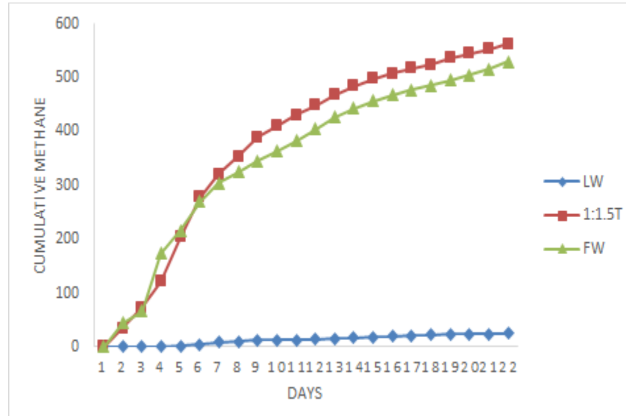


Figure 4: Methane Production of different samples



4. CONCLUSIONS AND DISCUSSIONS

It is concluded from this study of LW and FW and their different mixing ratio shows that LW with FW produce maximum methane production, while FW produces maximum biogas.Anaerobic digestion of LW can enhance methane concentration when it is co-digested with another waste substrate. LW is lignocellulosic substrate so it takes more time to digest. Thus, the co-digestion of LW with other substrate is a better option for methane production. Co-digestion of LW with FW is also an environmentally friendly step as no chemicals are used during this process. Also, there is no energy loss during the process which is generally used at the time of thermal pretreatment.

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