The Potential for Biogas Production from Grass

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Abstract: Grass is generally considered as one of the major agricultural products and covers over 90% of Irish agricultural land. While useful as an animal feedstock it can also be used for energy production. Here batch mesophilic anaerobic digestion of grass silage was studied. The methane concentration in the biogas clearly showed that grass silage has a high affinity to produce a high quality methane steam between 70-80%. Investigation of the effect of inoculum to substrate ratio on methane yield from grass silage using BMP (batch) anaerobic digester under mesophilic conditions, showed that the optimum I/S ratio is approximately 1 with a maximum methane yield of 0.385 m^3 kg^{-1}COD.

Keywords: *bio-gas, anaerobic digestion, grass silage*

1. Introduction

Research in sustainable energy has grown rapidly in recent years within both academic and industrial communities due increasing political, social and environmental pressures. While a number of potential options exist it is increasingly recognised that sustainable energy will utilise a significantly more diverse mix of energy generating facilities combined with effective energy storage. Biomass is nature's preferred method of solar energy storage and if used for renewable energy production, a wide range of materials can be included, such as wood, food waste, energy crops and grass. To date many researchers have worked on developing suitable processes for biomass conversion to achieve maximum energy with low cost. For example thermal processes through combustion and gasification can produce heat and electricity, however using biomass as a fuel for combustion produces at least the same air-pollution challenges as other fuels. There is also the conversion of biomass through biological processes directly to liquid biofuels (e.g. bioethanol) through fermentation or to biogas through anaerobic digestion (AD).

In essence AD is the natural decomposition of organic matter in the absence of air by bacteria into biogas, which consists of methane, carbon dioxide and other trace gases. Although the concept has been know for a long time the first modern biodigester was build in Bombay in 1859 and then brought to England in 1895 to produce biogas as a part of sewage treatment works.[1] Since then it has spread widely and is very successful in many developing countries due of the nature of the warm climate which is suitable for the processes involved. As a treatment strategy it has numerous environmental advantages over alternative processes including, lower odour, a lower quantity of biomass sludge produced in comparison with aerobic treatment and a higher degree of compliance with many national waste strategies being implemented to reduce the amount of biodegradable wastes entering landfill. [2] Additional benefits are obtained if both the renewable electricity and heat are utilised through combined heat and power within the same station thus reducing greenhouse gas emissions and increasing overall energy efficiency.

The above discussion highlights that biogas is considered to be an important component of the future renewable energy mix. Given its nature it has great flexibility to be converted to electricity, stored as a pressurised gas or cleaned and used in a gas grid or as a transport fuel. Many options exist for its production and of these grasslands show significant promise. To support this area the main objectives of this paper are to determine the potential for grass silage at different inoculum to substrate ratios.

2. Experimental and Materials for Biogas Production

2.1 Inoculum

The inoculum used to inoculate the BMP (Biochemical Methane Potential) reactors was from a mesophilic anaerobic digester obtained from the Agri-Food and Biosciences Institute (AFBI), N. Ireland which was treating cow manure. Prior to inoculation into the equipment, the inoculum was first sieved through a 1 mm mesh to remove any entrained solids or particulates. The sieved inoculum was analysed using standard methods to determine the Volatile solids (VS) Total suspended solids (TSS) Soluble and chemical oxygen demand (COD).

2.2 Grass Silage

The grass silage was obtained from an agricultural college from the Republic of Ireland. Upon receiving the effluent the liquid was sieved through a 1 mm mesh to remove any entrained solids or detritus. The total volume of filtered effluent was collected into a drum container and vigorously mixed to be homogenised. At this stage a sample was taken to determine the COD, pH, volatile fatty acid (VFA) and alkalinity. The pH was quite low so 1N NaOH was added to bring it up to pH 7 and then immediately frozen and kept at -20 °C in the freezer to prevent further degradation. Before analysis and feeding to the reactor, the samples were allowed to defrost overnight.

2.3 Biochemical Methane Potential (BMP)

The BMP reactor consisted of a simple sealed glass vessel with produced gasses collected using an inverted water filled column. Here four units were used, one containing inoculum alone (sludge) (R1), one with cellulose as a reference (R2), one containing silage with substrate to inoculum (S/I) ratio of 1 and one containing silage with (S/I) ratio of 1.5 (R4). In the test runs it was not practical to run triplicate sludge blanks due to equipment restrictions. The BMP tests were carried out once due to equipment availability, usually the blank assay is carried out in triplicate. Each assay was performed in a 1*l* reactor. A blank assay (only inoculum) was used to determine methane production resulting from inoculum itself and a control assay (cellulose) used as a reference to test the quality of the inoculum by comparing the results with other studies. The same amount of inoculum was added to each reactor. The inoculum was kept homogenous by continuous mixing. An appropriate amount of cellulose was added to R2 with inoculum to cellulose VS-ratio of 2:1, silage to inoculum ratio of 1:1 (COD silage to inoculum) in R3 and silage to inoculum ratio of 1.5:1 (COD silage to inoculum) in R4. All reactors were filled with distilled water up to 1.5 kg weight and 3g/*l* of $NaHCO_3$ was added as a buffer. 1.5 ml of trace minerals was also added to each reactor to improve the anaerobic reactors performance.[3]

Finally, the reactors were sealed and the headspace flushed with nitrogen to remove oxygen in order to enhance the anaerobic conditions in the reactors. These assays were continuously stirred while immersed in a temperature controlled water bath at 38 °C. The gases were piped from the reactor and periodically tapped off for analysis. The gas production volume and composition were recorded on a daily basis.

3. Results and Discussion

3.1 Inoculum and Silage Properties

Table (1) shows the substrate and inoculum properties used in BMP and armfield digesters. It is clear from the table that grass silage has a low pH which can be attributed to the high concentration of VFA's in the silage of above 800 mg/l. The increased VFA content could be as a result of the fermentation of the grass in order to form silage. The VFA's in the silage are then used directly in the acetogenesis stage to produce acetic acid, which is then used by the methanogens to produce methane.

Table (1): Substrate and inoculum properties

Substance	Suspended Solids(mg/l)	Volatile Solids (mg/l)	COD (mg/l)	pH
Sludge (inoculum)	23400	17890	350000	8.01
Silage	12170	10370	227500	3.88

3.2 BMP

As per the experimental section the BMP tests were carried out in four units, one containing inoculum alone (sludge) (R1), one with cellulose as a reference (R2), one containing silage with (S/I) ratio of 1 and one containing silage with (S/I) ratio of 1.5 (R4). Figure (1) illustrates daily biogas production for all reactors over a period of 40 days. For all of the reactors there is a sharp increase in the amount of biogas produced during the first 3-5 days of the experiment. This is then followed by a sharp decrease following the near complete consumption of the different substrates in the reactors. It can be seen that the maximum amount of biogas was produced for all reactors during the initial stages of the experiment. This was due to the increased availability of the biomass during the initial stages, leading to subsequent growth of the anaerobic organisms. After 4 days the rate of biogas production began to decrease due to a reduction in nutrient content. The weekly samples show that there was only a slight increase in pH from pH 7.3 – 8.01 over the course of the experiment for all reactors.

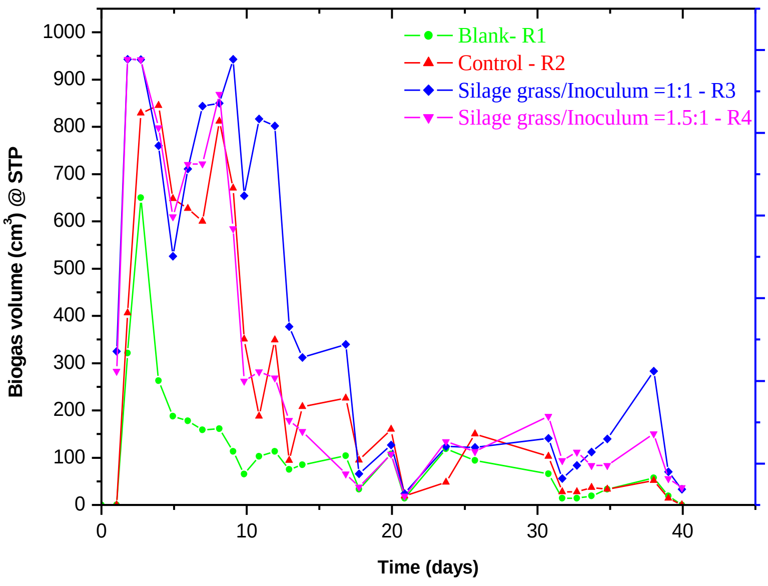

Figure (1): Daily Biogas Production @ STP

Figure (2) shows methane concentration in biogas samples as observed over the experiment period. It can be seen that for all reactors there are a sharp increase for methane concentration over the first 5 days for all reactors and then remains nearly constant for R1 and R3. A slight decrease for R2 and R4 was observed for remaining period. The methane concentration for R1, R2, R3 and R4 at the end of period is 69%, 62%, 83% and 72%, respectively. This can be attributed to the conditions at the beginning of the experiment which resulted in the growth of the different bacteria required to convert the high concentration of substrate available. Here the bacteria would have readily hydrolysed the compounds which break down quickly. This would have provided biomass for respiration for the methanogens and thus allowed for increased growth in the methanogenic cultures. After this substrate was consumed the availability of the feed for the methanogens would have been greatly reduced. Therefore the remaining biomass would be composed of tougher plant components which are not quickly hydrolysed and thus decreased methane production.

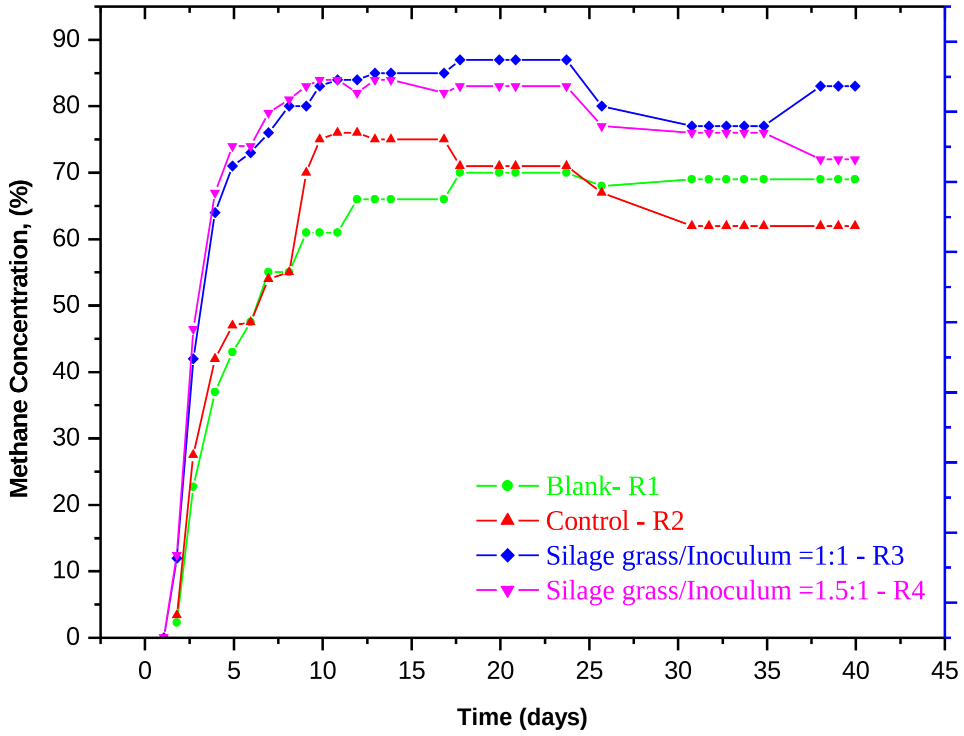

Figure (2): Methane Concentration in the Biogas

Using the above data the cumulative biogas production of all reactors at standard temperature and pressure (STP) (STP: 0 °C and 1 atm) can be measured allowing for a comparison with other literature. From this it can be observed that the silage produced a maximum biogas volume of 11.53 litres at (S/I) ratio of 1, 8.9 litres at (S/I) ratio of 1.5, 7.6 litres for cellulose and 3.15 litres for blank sample. The gas production in the blank R1 was the lowest, 3.15 litres, as expected but did produce some methane during the latter stages of the experiment. As before the majority of the methane produced in these test units was during the initial stages of the experiment. Again this was due to the increased availability of the biomass during these initial stages, leading to subsequent growth of the anaerobic organisms. After 10 days the rate of biogas production began to decrease due to reduction in nutrient content. It continued to fall to low levels at day 15 where it remained reasonably constant for the rest of the experiment.

4. Conclusions

Within this paper the AD of grass silage was investigated in a batch reactor. The methane concentration in the biogas showed that grass silage has a high affinity to produce a high quality methane steam between 70-80%. Investigation of the effect of inoculum to substrate ratio on methane yield from grass silage using BMP (batch) anaerobic digester under mesophilic conditions, showed that the optimum I/S ratio is approximately 1 with a maximum methane yield of 0.385 m^3 kg^{-1}COD.

Overall it can be concluded that the grass silage produces a methane rich biogas which can be used as an energy carrier or integrated within a larger process for the production of higher molecular weight products.

References:

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