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Effect of Substrate Composition on Anaerobic Digestion under Mesophilic Conditions

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Abstract: Energy supply and environmental protection are two crucial issues for the sustainable development of global prosperity. Anaerobic digestion is a well-known process to produce biogas from different municipal wastes and can be a solution for energy shortage. Wastewater can vary in composition, but the principal types of compounds present are carbohydrates, proteins and lipids. A laboratory scale study using semi-continuous batch reactors with multiple cycles was performed to understand the effects of different substrates: starch (model compound for carbohydrate), bovine serum albumin (BSA; model compound for protein) and acetic acid (model compound for lipids) and a mixture of all of them on the composition on biogas yield. Experiments were also carried out to determine the changes in acclimatization of methanogens for the targeted substrate using sludge from municipal wastewater treatment plant digester. For a fixed 0.5 g COD/ g VSS feed, bovine serum albumin showed a maximum 250 Nml gas production within 7 days of HRT. Mix, acetic acid and starch followed by 8.5, 9 and 10 days after 3 cycles, respectively. However, after the acclimatization of methanogens, the time to produce the maximum yield reduced to 5, 6, 6.5 and 7.5 days for protein, mix, acetic acid and starch after 6 cycles, respectively. The difference of rate for maximum gas productions was as follows: protein>mix>lipids>carbohydrates. Also, it was determined that the mix was the combined effect of each substrate; where each substrate contributes in the same proportion to the gas production.

1 Introduction

The world has faced a substantial increment of energy uses in last century. In most of the cases this increment is way faster than the available non-renewable energy production. Over 80% of the energy consumed today in the world is derived from fossil fuels[1]. However, this non-renewable energy production is directly linked with adverse effects on the environment. It has forced the researchers to find the alternative renewable energy sources. Unfortunately, a reliable, easily available and cost-efficient energy production is yet to be established. Biogas production from wastewater can be an easy solution of this problem if a proper and efficient method is developed [1,2]. Anaerobic digestion has been used long to produce biogas from different municipal and Industrial wastes. However, researchers are thriving to improve the efficiency of those anaerobic reactors. Specially, the production yield and behavior of organisms at different temperature and their relation to the substrate is not clearly established[3,4]. The current study was focused on maximizing production of biogas at different substrate for mesophilic conditions using batch reactors.

2 Methodology

A laboratory scale study using 300 mL sample volume semi-continuous batch reactors with multiple cycles was performed to understand the effects of different substrates: starch (model compound for carbohydrate),

BSA (model compound for protein) and acetic acid (model compound for lipids) and a mixture of all of them on the composition on biogas yield. Wastewater sludge from secondary treatment from the Chatham municipal wastewater treatment plant was the source of inoculum.

Mixture was a ratio of 1:1:1 for all of them. This ratio was chosen to find the contribution of each substrate with the same concentrations. Experiments were also carried out to determine the changes in acclimatization of methanogens for the targeted substrate using sludge from municipal wastewater treatment plant digester. In total 13 reactors were used, where each 3 for different substrate and one for blank. For acclimatization, 1st reactor for each substrate condition was feed and analyzed for three continuous cycles. The 2nd and 3rd reactor was run for 6 and 9 cycles respectively. Operating conditions for different substrate are explained in Table 1. Feeding was constant for all type of substrate with 0.5 g COD/ g VSS. Required micro and macro nutrients were also feed during the start of the cycle. Each cycle was completed when desired maximum 250 Nml gas production was attained and no further gas production was available. A sample was taken after each cycle from all the reactors to analyze VFA, solids concentration, total and soluble COD, NH_4+ and total phosphate.

Table 1 Operating conditions examined (at 37˚C)

Substrate used	Reactor number	Acclimatization cycle
Starch	1	3
Starch	2	6
Starch	3	9
Bovine Serum	4	3
Bovine Serum	5	6
Bovine Serum	6	9
Acetic Acid	7	3
Acetic Acid	8	6
Acetic Acid	9	9
Mix (1:1:1 ratio of Starch, Bovine Serum and Acetic Acid)	10	3
Mix	11	6
Mix	12	9

3 Key Results

For a constant 0.5 g COD/ g VSS feed, protein (BSA) showed the maximum gas production within 8 days of HRT after the 1st cycle. However, after 3rd cycle, when the reactor 1 was discontinued, all the reactors

(1, 2, 3) was showing an average of 7 days of HRT to get the same level of gas production. After the 6th cycle rector 2 and 3 was showing around 5 days HRT to produce the same level. After the 9th cycle, no further change was found to get the same level of gas production. As it can been seen the cycle length varies; it is complete when we reach the maximum gas production.

Acetic acid initially required 11 days HRT to get 250 nm gas production after 1st cycle. After 3rd, 6th and 9th cycle it was reduced to 9 days, 6.5 days and 6 days HRT respectively. For Starch, the initial 14 days reduced to 10, 7.5 and 7.5 HRT respectively. For mix, where an equivalent ratio of all the substrate was used, the initial 10 days (after cycle 1) reduced to 8.5, 6 and 6 days of HRT respectively. It is postulated that all the reactors with different substrates have acclimatised after 9th cycle.

4 Conclusion & Future study

After acclimatization periods, the rate of gas production was maximum for protein. For Mix and Acetic acid both showed the second highest and starch showed the lowest number. All the substrate showed that they almost reached their acclimatized stage after the 6th cycle.

Effects on VFA, COD, solids, NH_4+ and P for different substrates and their acclimatized periods is pending. Determination of bacterial colony by DNA analysis for the same effect is also pending for future work.

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