BIOLOGICAL CONVERSION OF BIOMASS TO METHANE

MASTER

QUARTERLY PROGRESS REPORT

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Complete-Mix vs. Multi-Stage Reactor Design

The advantages and need for mixing in the anaerobic fermentation of organic solids has been recognized. Because of the sequential nature of the microbial process, mixing has provided more stable systems that are less subject to operational problems. Recent reports in the literature have suggested that plug flow reactors are capable of providing higher rates of stabilization which result in greater methane production per unit volume of reactor. It has also been reported that separation of the acetogenic stage from the methanogenic stage increases the gas yield.

The results of this study clearly show that if a balanced population of organisms can be maintained in the initial stage, multi-stage fermentation is more efficient than a complete-mix system. However, if the system is stressed, failure of the multi-staged system is more rapid. When the first stage is not inhibited due to a short retention time, the waste stabilization in the additional stages is minimal. With a balanced microbial system in the first stage, it would appear that the optimum retention time in this stage is approximately 2.0 days when operating at a 60°C fermentation temperature.

The rate constants calculated for the first stage complete-mix reactors are given in Table 1. These constants are calculated from the following equation:

$$S_e = S_o \left(\frac{1}{1 + K\theta} \right)$$

where: S_e = Effluent substrate level

S_o = Initial substrate level

θ = Retention time

The variation in these constants can be attributed to two primary factors.

First, the stress applied to the biological populations as evidenced by high organic acids and low pH reduce the rate at which the solids are

Table 1. Variation of K with Retention Time

θ Days	K - Day ⁻¹	
	Vol. Solids	COD
14.6	0.197	0.162
10.0	0.190	0.205
10.0	0.289	0.252
8.0	0.238	0.388
6.0	0.225	0.221
5.0	0.461	0.471
4.0	0.445	0.511
3.7	0.309	0.278
3.3*	0.277	0.095
3.0	0.269	0.203
2.5	0.509	0.446
2.5*	0.304	0.275
2.0	0.699	0.769
1.5**	0.023	0.000

* Biological population stressed - High volatile acids

** System failure due to short retention time

hydrolyzed and the COD stabilized. The calculated constants for these reactors have lower values.

The effect of retention time on the rate constant is very great. This would appear to result from the complex nature of the substrate. In the short retention times, the easily degraded organic material was rapidly stabilized. However, with the longer retention times, the microorganisms had to use more resistant substrates. This resulted in a decrease in the rate constant.

These data clearly show that this kinetic relationship is not valid since K is not constant. Because of the complex nature of the substrate, it is doubtful if any kinetic model can be adequately fitted to these data. It would appear that no single substrate component can be identified as the limiting substrate. At the very short retention times, methanogenesis is rate limiting. For the intermediate retention times, hydrolysis of certain constituents of the fiber is rate limiting. At longer retention times, breakdown of the more complex fibers appear to be the rate limiting step. The lack of a defined limiting substrate significantly complicates the kinetic modelling.

These very high values of these constants for the short retention times show that most of the organic material has been stabilized in the first-stage reactor. Data collected on the reduction of organic material through subsequent stages show very little additional reduction except when the first stage is stressed and has a low value for K .

This study has shown that exceptionally high rates of stabilization of complex organic material can be expected. The type of reactor design desired will depend upon the objective of the system. If it is desired to maximize the conversion of solids to methane, a staged system will produce more methane per unit volume of reactor for a given quantity

of substrate. If the objective is to maximize methane production per unit volume of reactor, a single-stage reactor operating at near the minimum retention time is required.

A final report on this phase of the contract has been prepared and a draft submitted to contracting agency for approval.

Manure Fermentation Studies

The manure fermentation studies have been completed. Data have been collected on the conversion efficiency at 60°C and 40°C. A high degree of variation existed in the gas yield per unit of volatile solids fed. The variation in the manure characteristics from the open lot was substantial, resulting in the high variability of gas production rates.

In addition to the gas production rates, data have been collected on the dewatering characteristics of the slurry from the fermentor. Dewatering processes evaluated included vacuum filtration and centrifugation. Also data were collected on particle size distribution as related to screening.

The composition of the fermentor slurry and the various size fractions were determined. Cellulose and lignin values as well as the nitrogen, phosphorus and potassium levels were measured.

A final report containing all of the data collected during this phase of study is being prepared.

Corn Stover Fermentation

The next phase involves the evaluation of the fermentation characteristics of corn stover. Approximately eight tons of this material

was harvested during the fall. The material is chopped prior to adding to the slurry tanks. After soaking for 24 hours, the slurry is discharged to the mixing tanks from which it is pumped to the fermentors.

This slurry is extremely difficult to handle. Pump and pipe clogging is extensive and has prevented any semi-continuous operation. Gas production to date has been very low, approximately 0.275 m^3 per kg volatile solids added. These data were obtained from systems operating at a 15-day retention time and 60°C temperature. The investigation presently is concentrating on ways to enhance this gas production. Thermal pretreatment, thermal-chemical pretreatment and particle size are being investigated.