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DEVELOPMENT OF BIOLOGICAL COAL GASIFICATION (MicGAS PROCESS)

9th Quarterly Report

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Submitted to:

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DISCLAIMER

DEVELOPMENT OF BIOLOGICAL COAL GASIFICATION (MicGAS PROCESS)

Tasks 1 and 2:

These tasks have been completed.

Task 3 - Coal-Microbial Interactions:

Subtasks 3.1 - 3.2

These subtasks have been completed.

Subtask 3.3 - Solids Loadings

Laboratory scale studies examining biogasification of Texas lignite at various coal solids loadings have been completed. Bench scale bioreactors are currently being used to scale up the biogasification process to higher coal solids loadings (5% and 10%).

Task 4 - Biological Production of Methane from Coal: Optimization of the Process:

Subtask 4.1 - Selection of Co-substrates

In current biogasification medium formulations, both Sheftone T and a solution of B-vitamins are used. However, the manufacturer's description of the composition of Sheftone T indicates that it may contain adequate vitamins for the biogasification process. If the addition of vitamins can be avoided, the cost of the medium will be reduced.

Medium containing Sheftone T (0.2% w/v) was prepared without vitamin solution. Test bottles were supplemented with the appropriate volume of B-vitamin solution. Inoculum consisted of Mic-1 which had been centrifuged and resuspended in medium without B-vitamins. The inoculated bottles were incubated at 37°C. Total gas production, as well as the composition of the gas, was measured at weekly intervals.

As shown in Figure 1, methane production was not effected by the absence of B-vitamin solution. In fact, after 14 days of incubation, methane production was somewhat higher in cultures without additional vitamins (198 cc/gram of coal) than in culture which contained the additional vitamins (156 cc/gram of coal). These results indicate that B-vitamin solution need not be added to the biogasification medium when Sheftone T is used at 0.2% (w/v).

Subtask 4.2 - Isolation and Characterization of Bacteria

Characterization of the bacterial isolates obtained from Mic-1 and Mic-4 to date has shown that none of these microorganisms are responsible for the primary degradation of Texas lignite. It has been hypothesized that primary coal degradation may be the result of synergistic activity (i.e. activity of two or more different bacteria). Efforts are underway to pursue this idea by enriching various bacterial sub-populations within the biogasification consortia.

Several of the isolates obtained thus far have been found to be aerotolerant (able to survive exposure to air) rather than strict anaerobes (killed by exposure to air). It is possible that the bacteria responsible for degradation of coal belong to the group of aerotolerant bacteria. To test this, a culture of Mic-1 was aerated to oxidize the medium and kill any strict anaerobic bacteria such as the methanogens. This culture was then reduced and used to inoculate medium with and without Texas lignite. Soluble carbon and volatile fatty acids concentrations in the liquid phase, as well as gas production, was monitored.

It was expected that aerating the culture for the inoculum would have eliminated the strict anaerobes, especially the methanogens. This would result in an increase in soluble carbon in the liquid phase because the carbon would not be converted to methane. However, there was no increase in soluble carbon in the cultures containing coal (Table 1). Surprisingly, methane was produced during incubation. Epifluorescence microscopy confirmed that viable methanogens were still present in the cultures. This indicates that the aeration did not completely oxidize the inoculum. Therefore, complete selection of aerotolerant bacteria did not occur.

Subtasks 4.3 - 4.4

No work was scheduled for these subtasks.

Subtask 4.5 - Bioreactors Studies

In order for the MicGAS process to become economically favorable, it is necessary to increase the coal solids loadings. A study by Fluor Daniels determined that coal solids loadings of 20% or greater should be used. In previous studies, biogasification of Texas lignite at 1% and 5% (w/v) was demonstrated using a rotating biological contactor (RBC). Another RBC reactor was set up with a coal solids loading of 10% (w/v). This reactor was described in the 8th Quarterly Report.

Initially, methane production rates were high (4800 cc produced during the first 10 days). However, methane production

decreased over the next month. It was hypothesized that the decrease in methane production was due to a loss of methanogens. To test this, fresh Mic-1 was added to the reactor as a source of viable methanogens, and methane production was monitored for another month. However, methane production continued to decline. Operation of this reactor was discontinued after approximately two months.

Biogasification of pulverized Texas lignite at 10% (w/v) solids loadings was also examined in three upflow bioreactors. These reactors were described in the 8th Quarterly Report. After four days of incubation methane concentrations of 48-50 mole% were obtained in the headspace in all three reactors. However, gas production decreased rapidly after this time. It was hypothesized that this was due to inadequate mixing of the coal with the liquid phase. Although the headspace gas was recirculated through the medium to mix the coal, the coal particles in these reactors became compacted and had a tendency to clog the recirculation ports. These reactors were discontinued after approximately one month.

To avoid the problems of clogging and poor circulation associated with pulverized coal, the three upflow reactors were again set up using Texas lignite of 10 mesh (>1.0 mm). The reactors contained 0, 5 or 10% (w/v) coal. Each reactor was inoculated with 4% (v/v) Mic-1, 4% (v/v) Mic-4 and 2% (v/v) sewage sludge. The headspace gas was recirculated through the liquid phase to facilitate mixing. Total gas, methane and carbon dioxide production, as well as cellular protein, volatile fatty acids and soluble carbon concentrations were monitored.

Total gas produced, methane and carbon dioxide concentrations and pH of the upflow reactors after twelve days of incubation are presented in Table 2. There was little difference in total gas production between the two reactors containing coal. The methane concentration in the headspace was slightly higner in the reactor containing 5% Texas lignite (18.2%) than in the reactor containing 10% coal (16.6%). The carbon dioxide concentration was also highest in the 10% coal reactor. The control (no coal) reactor produced the lowest volume of total gas and contained the lowest concentrations of methane and carbon dioxide. The lower methane production in the 10% coal reactor may be due to the lower pH (6.7) of the liquid phase, as methanogens are generally inhibited by low pH. The low pH is probably due to the greater carbon dioxide concentration. Operation of these reactors is continuing.

Conclusions:

In Summary:

- Methane production was not curtailed when B-vitamin solution was not added to the biogasification medium.
- Aeration of Mic-1 did not sufficiently oxidize the medium to eliminate strict anaerobic bacteria (i.e. methanogens).

Planned Future Work:

- Determine if H_2S is produced from sulfur present in Texas lignite.
- Evaluation of various bioreactor designs using high coal solids loadings.

Table 1. Soluble carbon (COD) in the liquid phase of aerated Mic-1 cultures with and without Texas lignite.

Sample	COD (μg/ml) Day 0	Day 7	Day 14
+ Texas lignite	1077.2	1063.1	537.5
- Texas lignite	1261.8	1280.8	935.2

Table 2. Gas production and pH of upflow reactors after 12 days of incubation.

	cc of Total gas	percent CH_4	percent CO_2	pH
no coal	122	6.6	5.8	7.6
5% Texas lignite	228	18.2	9.7	7.3
10% Texas lignite	237	16.6	16.1	6.7

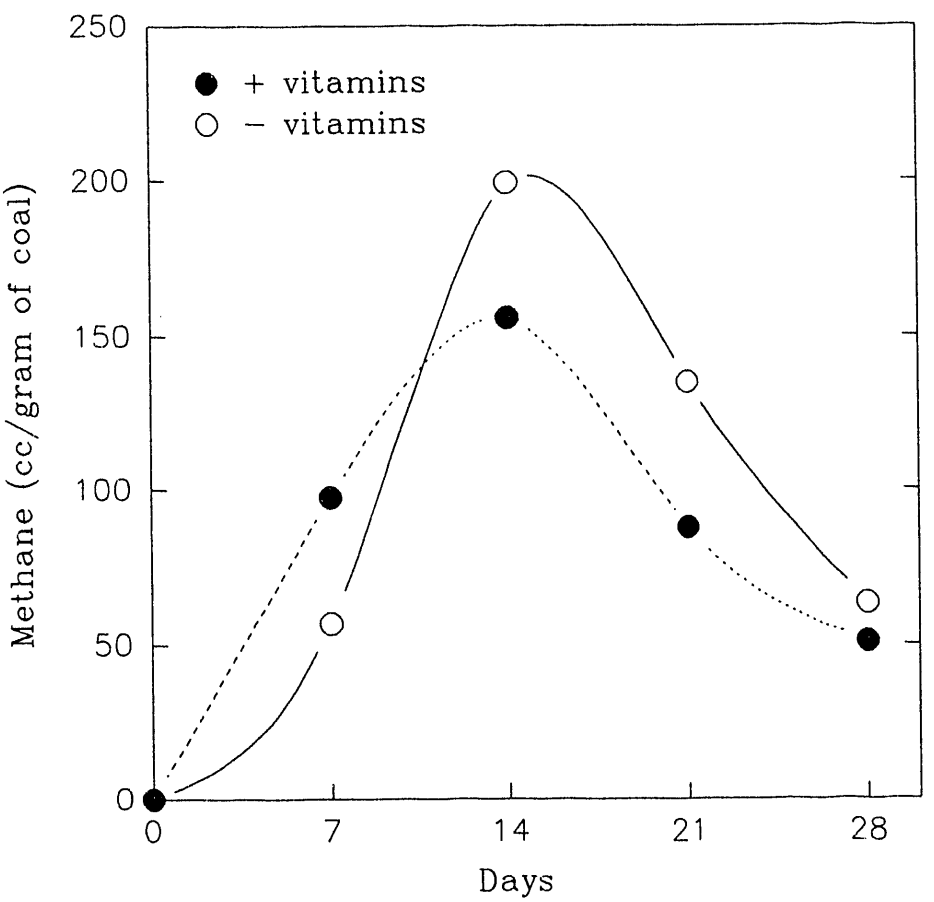

Figure 1. Methane production from Texas lignite by Mic–1 with and without added B–vitamin solution.

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