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ECONOMIC AND KINETIC STUDIES OF THE PRODUCTION OF CHEMICALS AND FARM ENERGY BY FERMENTATION OF BIOMASS

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MASTER

FARM ENERGY SYSTEM

The farm energy system, shown schematically in Figure 1, has been constructed on a farm in Drury, Missouri. The purpose of this unit is to demonstrate the feasibility of producing energy for farms (heat and electricity) from methane produced by anaerobic digestion of crop residues and other crop materials.

The system consists of four 4,000 gallon digestors equipped with axial agitators. The reactors are housed in an insulated building maintained at 95°F. Crop matter is fed to the digestors on a sixty-day batch cycle. Methane produced is stored in PVC bags and used to generate electricity or for heat in the farmhouse. Waste heat from the engine-generator is used to heat the building.

The system was started in early summer by inoculating five percent hay-water mixtures with sewage sludge. Start-up went smoothly with gas production reaching a maximum within two weeks, as shown in Figure 2. Control of pH required frequent lime addition during the first week, but lime additions were not necessary after this period to maintain $\text{pH} > 7$. Methane concentrations were between 45 and 65 percent and averaged above 50 percent. After sixty days carbon destruction was 50 percent.

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Figure 1. Schematic of Farm System

FARM DEMONSTRATION UNIT

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 Reactor 2
 Batch A

Agricultural Residue Orchard Grass
 Startup Date May 31, 1979

Batch Size 3000 (Gallons)
 Percent Residue 5 (%)
 Culture/Residue Ratio 5:1

DAILY AVERAGE GAS PRODUCTION RATE (Cubic Feet per Day)

CARBON DESTRUCTION (%)

METHANE / CARBON DIOXIDE RATIO (% Methane)

Figure 2. Farm Reactor Data

The performance of batch laboratory reactors using the same hay as the farm system is shown in Figure 3. These laboratory reactors are operating with ten percent hay initially and three cycles of several weeks duration are shown. Each cycle is re-inoculated from the previous culture. The same performance cycle as the farm reactors is apparent with maximum gas production occurring after two weeks. Carbon destructions have been poor, but improve with each cycle. Methane concentrations are consistently above 50 percent. These lab reactors are operated to determine the best inoculation sequence for the farm reactors and to study possible problems with culture nutrient deficiencies and aging.

The initial agitator drive mechanism consisted of two pneumatic cylinders driving all four agitators through a linkage shaft. This concept minimized the energy input, but introduced severe mechanical problems with proper alignment. This system is presently being modified with a pneumatic cylinder on each reactor. Since only periodic agitation will be used, the additional energy consumed will not be excessive.

The engine-generator has been installed and satisfactorily tested with biogas. A 10 hp induction motor is used as the generator. Negotiations with the local utility for the sale of electricity are underway.

Three replications of field plots were established at the Southwest Center near Mt. Vernon, Missouri, in order to evaluate cropping mixtures for biomass production. Each plot is 30 by 100 feet so that enough material will be produced for evaluation of methane production in pilot studies. Treatments include double cropping winter rye and sorghum-sudan or corn, intercropping tall fescue and red clover or alfalfa or orchardgrass, and monoculture of warm-season perennials such as caucasian bluestem and indiangrass. Plots

Figure 3. Laboratory Digester Performance

of the rye component and the cool-season forage mixtures were seeded this fall. The warm-season annuals and perennials will be seeded next spring.

ACID HYDROLYSIS/FERMENTATION STUDIES

The acid hydrolysis pre-treatment of corn stover studies utilize a two stage sulfuric acid contact. In the first stage, dilute sulfuric acid is used to hydrolyze the pentosan fraction of ground biomass. The second stage uses concentrated sulfuric acid for hexosan hydrolysis. The use of the two steps give high yields, possible with concentrated acid, without the problems of pentose decomposition.

Figure 4 gives a typical concentration profile for the pre-hydrolysis step. This hydrolysis is carried out at 98°C with 4.4 percent acid. Figure 5 gives the profile for the second stage with 85 percent acid also at 98°C. As noted, only small quantities of glucose are produced in the pre-hydrolysis. No xylose is present in the hydrolyzate, indicating complete conversion of pentosans in the pre-hydrolysis.

A series of studies is being conducted to determine the optimal temperatures, acid concentrations and reaction times for both steps. Fermentation of the hydrolyzate fractions will begin when these studies are completed.

Figure 4. Sugar Formation in Prehydrolysis Step

Figure 5. Sugar Formation in Second Hydrolysis