BIOLOGICAL CONVERSION OF BIOMASS TO METHANE

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1. Introduction

After completion of the fermentation studies using manure as the substrate, a series of tests were designed to evaluate the gas yield from corn stover. Corn stover is the residue remaining in the fields after the grain has been harvested. Because the grain is shelled off the cob, stover contains the cob, stalk and leaves of the mature corn plant. Stover was collected from the corn fields adjacent to the laboratory. The material was collected mechanically and consisted of the above ground plant material that had either been cut or broken from the stem during grain harvest. Several wagon loads of stover were collected and stored in a covered storage area.

The particle size of the collected stover was large, with corn stalks up to approximately 30 cm in length. Prior to feeding to the fermenters, the corn stover was milled so that it would pass through a 6.3 mm screen initially and at a later date, through a 3.2 mm screen.

2. Particle Size Distribution

The particle size distribution of the fermented solids plays a major role in determining the solids recovery potential. Also, the composition of these different size fractions will be important in evaluation of by-product recovery systems. The particle size determination was made using a wet sieving technique described in detail elsewhere (1). A known volume of effluent slurry was passed through a series of sieves. The solids retained on each sieve were washed with a fixed volume of distilled water with the wash water being passed through each successive sieve. The sieves and the retained solids were oven dried and the dry weight of the retained solids determined. The solids passing through all of the

sieves were determined by sampling the water collected from the sieves. Standard dry sieving techniques were utilized to determine the particle size distribution for the dry feed material after passage through either the 3.2 or 6.3 mm screen.

Typical size distribution for the feed and reactor effluent slurries are given in Table 1. For comparative purposes, data for manure fermentation are included. The reactor processing the manure was operated at 58°C and a 10 day residence time with a total solids content of 5.34 percent. The reactor processing corn stover was operated at 58°C and a 12 day residence time. The total solids content in the reactor was 3.44 percent. The raw manure slurry contained solids passed through a 6.3 mm screen. The total solids content of the slurry was 4.49 percent. The raw corn slurry solids were passed through a 3.2 mm screen and the slurry solids concentration was 6.73 percent.

These data show that a significant portion of the volatile and the total solids in the feed as well as the fermented slurry passed the 200 mesh screen. These solids represent small suspended and colloidal solids plus dissolved solids. There were some significant differences in the size distribution of these slurries. The proportion of raw manure that passed through the larger screens was greater than for the raw corn stover, even though the corn was passed through the smaller (3.2 mm) screen when milled. The proportion of large solids in the manure slurry decreased even more upon digestion. The opposite was true for the corn stover. After digestion, the solids appeared to increase in size. This may have been due to the absorption of additional water during the relatively long residence time in the reactors.

Table 1. Particle Size Distribution

Sieve Size	Percent of Solids Retained			
	Total Solids	Volatile Total Solids	Suspended* Solids	Volatile* Sus. Solids
Reactor #1 Effluent (Manure Feed)				
10	12.1	14.7	25.4	29.5
20	21.9	25.6	46.0	53.2
50	35.0	41.4	74.5	82.6
100	40.6	45.4	85.3	90.6
200	47.6	50.1	100.0	100.0
Pan	100.0	100.0	--	--
Reactor #3 Effluent (Corn Feed)				
10	61.4	74.0	78.0	83.0
20	65.8	78.0	83.0	87.0
50	72.4	85.0	92.0	94.0
100	76.3	82.0	97.0	98.0
200	79.1	90.0	100.0	100.0
Pan	100.0	100.0	--	--
Raw Manure Slurry Mixing Tank #2				
10	34.0	35.5	59.6	85.2
20	38.7	41.0	67.9	81.2
50	49.6	52.3	87.0	86.1
100	53.8	57.0	94.4	93.5
200	57.0	60.3	100.0	100.0
Pan	100.0	100.0	--	--
Raw Corn Slurry Mixing Tank #1				
10	41.7	52.0	75.9	77.9
20	46.2	57.8	84.1	86.6
50	51.2	58.0	93.1	93.8
100	53.4	60.4	97.2	97.4
200	54.9	62.1	100.0	100.0
Pan	100.0	100.0	--	--

*Suspended solids are considered to be those solids retained on the 200 mesh sieve

The distribution of suspended solids as defined for this study is of more importance. The insoluble solids passing the 200 mesh sieve (74 μm) will generally require chemical coagulation before they can be removed. This will greatly increase the cost of processing these solids. The majority of the "suspended" solids can be removed as a relatively large particle. In all of the manure slurries tested, 85 to 90 percent of the solids retained on the 200 mesh screen were retained on the 100 mesh screen. With the exception of the reactors operated at long retention times (10 days at 58°C and 15 days at 40°C), the 50 mesh screen retained 90 percent of the "suspended" solids.

An even greater percentage of the fermented corn stover was retained on the large sieves. The 10 mesh sieve captures 80 to 90 percent of the "suspended" solids in the effluent from the reactors receiving corn stover. There were two distinct size ranges in the corn stover slurry. Approximately 42 percent of the total solids were retained by the 10 mesh screen. An additional 13 percent of the total solids were retained on the 200 mesh screen while 45 percent passed through the 200 mesh screen.

Figure 1 shows the particle size distribution of corn milled on both the 3.2 mm and 6.3 mm screen. The manure milled on the 6.3 mm screen is included as a comparison. The dry corn milled in the 6.3 mm screen is retained to a greater degree on the three largest mesh sizes. The majority of the wetted feed and digested effluent solids are either retained on the 10 mesh screen or pass the 200 mesh screen. Approximately 65 percent of the fermented corn stover slurry "suspended" solids can be removed by 2.0 mm screen.

Figure 1. Corn-Particle Size Distribution at Various Process Stages

3. Gas Production Rates

One of the primary objectives of these tests was to determine the efficiency of the methane fermentation system in converting the corn stover into methane. The four fermenters were operated under various conditions in an attempt to obtain good gas production. Reactor 3 was operated as a control, with the retention time maintained in the 13 to 15 day range. The average loading rates and gas production data for this reactor are given in Table 2. The corn stover feed to the system up to Day 78035 was milled through the 6.2 mm screen. The balance of the stover was milled through the 3.3 mm screen.

The data in Table 2 do not show any significant variation in gas production for the different size feed material. The relatively low gas production during the week ending on 78028 was a result of recycle of an excessive quantity of inert organic solids. Prior to Day 78021, the effluent from the fermenters was dewatered with the Sharples conveyor centrifuge, and the centrate recycled. Because of problems of plugging with the centrifuge, the reactor effluents were dewatered on a screen. Many small organic solids were recycled with the liquid. When this problem was identified, the bulk of the solids in the effluent was removed by screening. The liquid was then centrifuged prior to recycle. This practice was started on Day 78035 and continued until Day 78083.

The weather presented some major problems with operation and may be responsible for some of the data variation. A blizzard on Day 78026 and again on Day 78043 isolated the lab for 3 and 2 days, respectively. Of course, during this period, the reactors did not receive any substrate. From Day 78083 through Day 78086, an ice storm disrupted the power to the

Table 2. Gas Production from Reactor #3

Week Ending	θ Days	Gas Lph	Feed Kg V.S.	CH ₄	
				%	M ³ /kg V.S.
77358	18.5	15.7	1.68	55.1	0.123
78000	14.3	14.8	1.37	-	-
07	14.1	13.7	1.43	55.5	0.128
14	15.6	11.5	1.13	57.5	0.140
21	14.5	11.4	1.26	55.3	0.120
28	15.2	12.5	1.50	53.4	0.107
35	14.4	17.1	1.87	53.8	0.118
42	14.6	17.8	1.79	54.9	0.132
49	13.4	20.2	2.00	50.9	0.123
56	14.6	20.1	2.08	51.0	0.118
63	14.3	21.6	2.21	52.6	0.123
70	13.9	24.1	2.16	53.1	0.142
77	15.0	24.5	2.40	53.9	0.132
84	15.0	27.6	2.33	53.0	0.151
91	13.2	15.1	2.92	53.4	-
99	13.8	16.1	1.81	52.9	0.113
106	14.2	13.1	1.83	52.8	0.097
113	13.3	10.8	2.00	52.9	0.069
120	13.0	15.3	2.01	55.1	0.100

lab. Fortunately, the ambient temperature did not drop much below freezing. Therefore, even though the heat in the building was off, no freezing problems were caused by the low temperature.

The gas production from Reactor 1 is shown in Table 3. After an initial period of acclimation to corn stover, a thermochemical pretreatment step was introduced. Milled corn stover was mixed with lime (3 percent by weight of lime) and added to a pressure reactor. Water, generally recycled liquid, was added to this tank to increase the moisture to approximately 75 percent. Steam was then added to maintain a temperature of 110°C for approximately 4 hours. On Day 78058, the lime was increased to 6 percent by weight and on Day 78079 to 10 percent by weight. There is no apparent improvement in gas production as a result of this pretreatment. After heating for a 4 hour period, the pH of the 10 percent lime treatment was in the range of 9.1 to 9.3. Additional water was added to this tank to obtain the desired slurry concentration before transfer to the holding tank.

Reactor 2 received the same treatment as Reactor 1 (see Table 4). The only variable was a reduced retention time during part of the period. The feed particle size for these reactors was the same as that fed to the control. The thermochemical pretreatment was terminated on Day 78098. The feed to all reactors was the untreated corn stover and the retention times were changed in preparation for obtaining some rate data.

The data for Reactor 4 are shown in Table 5. This reactor was initially intended to duplicate Reactor 3. However, excessive variations in the temperature caused erratic data. It was necessary to shut this reactor down and correct the temperature control problem. This reactor

Table 3. Gas Production from Reactor #1

Week Ending	θ Days	Gas Lph	Feed Kg V.S.	CH ₄	
				%	M ³ kg V.S.
78014	14.6	14.4	1.54	55.0	0.123
21	14.7	12.8	1.24	56.4	0.140
28	13.9	13.7	1.24	53.8	0.143
35	13.7	11.2	1.10	54.6	0.133
42	13.7	12.8	1.28	54.5	0.131
49	13.1	13.8	1.62	53.4	0.109
56	13.7	11.5	1.62	53.2	0.091
63	14.4	14.0	1.56	53.2	0.115
70	14.3	17.4	2.12	51.7	0.102
77	14.6	19.5	2.23	55.3	0.116
84	14.0	20.7	2.64	55.7	0.105
91	14.5	26.9	2.88	52.9	0.118
98	13.9	30.0	2.54	54.2	0.154
108	7.2	17.4	3.93	53.3	0.057
115	7.3	18.4	4.02	53.0	0.058
122	7.6	17.1	3.22	55.6	0.071

Table 4. Gas Production from Reactor #2

Week Ending	θ Days	Gas Lph	Feed Kg V.S.	CH ₄	
				%	M ³ /kg V.S.
78014	13.7	17.5	1.73	54.0	0.131
21	14.7	13.9	1.24	54.6	0.147
28	14.6	13.5	1.17	53.0	0.147
35	13.7	10.9	1.10	54.4	0.129
42	14.2	15.2	1.23	53.9	0.159
49	13.6	14.9	1.66	53.6	0.115
56	13.2	14.1	1.68	52.8	0.106
63	13.9	14.1	1.81	53.7	0.100
70	10.6	21.8	3.0	52.6	0.092
77	8.5	28.8	3.91	54.1	0.096
84	8.8	30.3	4.09	54.4	0.097
91	10.7	37.7	4.40	52.9	0.109
98	9.0	38.1	3.88	53.8	0.127
108	4.9	23.3	5.7	53.1	0.052
115	5.0	25.8	5.9	53.9	0.057
122	5.1	16.0	4.7	54.7	0.045

Table 5. Gas Production from Reactor #4

Week Ending	θ Days	Gas Lph	Feed Kg V.S.	CH ₄	
				%	M ³ /kg V.S.
78014	14.6	12.1	1.24	57.3	0.134
21	14.6	12.5	1.26	55.6	0.132
28	14.8	13.0	1.53	52.6	0.107
35	14.3	16.9	1.88	53.5	0.115
42	13.9	16.3	1.90	54.5	0.112
49	13.3	22.4	2.08	51.1	0.132
56	13.4	20.3	2.30	51.4	0.108
63	13.0	19.6	2.51	51.9	0.097
70	13.7	17.2	2.27	50.1	0.091
77	13.9	24.8	2.56	53.7	0.125
108	3.7	21.2	7.25	50.9	0.036
115	3.9	25.4	7.45	54.3	0.044
122	3.9	30.5	6.61	54.6	0.060

was reseeded and started again for the rate studies. The methane production data during this period from Reactors 1 through 3 are summarized in Table 6.

Table 6. Methane Production Rates

Control (3)		Reactor 1		Reactor 2	
θ (days)	$\text{m}^3/\text{kg V.S.}$	θ (days)	$\text{m}^3/\text{kg V.S.}$	θ (days)	$\text{m}^3/\text{kg V.S.}$
<u>Lime - 3%</u>					
14.8	0.126	14.4	0.135	14.2	0.139
14.2*	0.125	13.5	0.110	13.7	0.127
<u>Lime - 6%</u>					
14.4	0.132	14.4	0.110	11.0	0.096
<u>Lime - 10%</u>					
14.4	0.132	14.1	0.129	9.8	0.111

* Size of milled stover reduced from 6.3 to 3.2 mm

The effects of any pretreatments employed were insufficient to show any trends. There was significant variation in the data. This variation was due to a number of factors, some of which have been previously discussed. However, any significant improvement in biodegradability would have been obvious. Approximately 30 percent of the volatile solids were being fermented. An increase in the biodegradability to 50 percent would have resulted in methane productions of approximately 0.2 m^3 per kg volatile solids added. Clearly no such increase occurred.

In order to determine the effect of retention time on the gas production rates, a run was made using retention times ranging from 3.8

days to 13.5 days. Although the reactors are designed to be fed continuously, it was not possible to do so with this corn stover. Continuous feed requires the feed pumps to operate on a time switch, pumping at short intervals during the day. Unfortunately, the stover slurry would not pump without an initial flush with water. Once the slurry was pumping, there were no problems. Therefore, it was necessary to manually operate the feed pumps. The reactors were fed 50, 100, 150, and 200 liters per day. The appropriate volume was fed in 50 liter quantities in order to reduce the surge effect at the high feed rate.

During this period, the recycle water contained substantial quantities of volatile solids. These solids were measured and with the volume of recycle water used, allowed for the calculation of the contribution these solids made to the volatile solids fed to the reactors. During the above study, the recycled volatile solids were 20 percent of the feed volatile solids.

The methane production at various retention times is given in Table 7. The gross production refers to the total volatile solids fed, including recycle solids. The net column has been calculated on the basis of the volatile solids added as unfermented corn stover. The gas production from this material is very disappointing. The potential for developing an economically viable system for producing a fuel gas via microbial fermentation from corn stover is greatly diminished.

Table 7. The Effect of Retention Time in Methane Production

Days	m ³ /kg Vol. Solids. Fed	
	Gross	Net
3.8	0.047	0.059
5.0	0.051	0.064
7.4	0.062	0.078
13.5	0.087	0.110

4. Centrifuge Dewatering Study

The objective of the centrifuge dewatering study is to evaluate the efficiency of the centrifuge in solids capture and solids dewatering. A Sharpless Mark III solid bowl-basket centrifuge with a variable speed drive was used to conduct the dewatering tests. This unit does not provide for continuous cake discharge; therefore, a predetermined amount of slurry which will insure that the bowl is not overloaded with solids was fed to the centrifuge. The centrate retained in the bowl at the end of the run was withdrawn by the use of a skimmer pipe.

Centrifugation studies were conducted on the fermented corn stover slurry with the results shown in Figure 6. Reactor 1 was receiving a feed of corn stover that had been thermochemically pretreated with 10 percent by weight (dry solids) of lime at 110°C for 4 hours. The feed slurry for Reactor 3 was untreated. Both reactors were operated at 58°C and a 15 day residence time. The maximum cake solids were obtained at 2400 (1150xg) and 2600 rpm (1300xg), the maximum speeds used on the samples from Reactors 1 and 3, respectively. It would appear that higher speeds would produce a drier cake. The thermochemical pretreatment significantly improved the dewatering characteristics of this slurry. Also, the slurry from the fermentation of the corn stover dewatered better in the centrifuge than the beef manure.

There was a marked difference in the centrate solids from the two reactors. This may be due, in part, to the high solids content of Reactor 1 (6.06 percent) compared to Reactor 3 (3.01 percent). Also, the lime added for the pretreatment will increase the dissolved solids. The flat curves show that there is little possibility of improved solids capture with increasing centrifuge speed.

Figure 6. Cake Solids and Centrate Solids Produced During Centrifuge Tests (Corn Slurries)

5. Vacuum Filtration Studies

A common technology for slurry dewatering involves filtration mechanisms ranging from simple screens to filter belt presses. One such system that has evolved is the vacuum filtration process. This process has been widely used to dewater slurries from many sources. A laboratory filter leaf test procedure was used for evaluation of the filtration characteristics of these slurries. This procedure employs a section of filter cloth that is commercially available for installation on a vacuum filter. The test cloth is subjected to the same sequence of operations encountered in an operating vacuum filter. The data obtained from these tests can be used for predicting the response of the full scale system.

The dewatering characteristics of the slurry can be changed by chemical conditioning. Various chemicals can be used to improve the filtration characteristics. Iron salts, especially ferric chloride, are effective in this chemical conditioning. The addition of organic polymers has also been found to be of assistance.

A series of tests using the filter leaf test procedure was undertaken using three different media as follows. These media were obtained from the Eimco BSP Division of Envirotech Corp.

- PO-808 - Polyethelene monofilament yarn, 1/1 plain₂ weave, 40 x 23 thread count at 10.5 oz/yd²
- NY-415 - Nylon monofilament yarn, 1/1 plain weave, 40 x 40 thread count at 5.7 oz/yd²
- POPR-859 - Polypropylene monofilament yarn, 2/2 twill weave, 60 x 30 thread count at 8.5 oz/yd²

The NY-415 was the most porous of the three media used, while POPR-859 had the tightest weave. As would be expected, the media plays a key role in determining the response of the slurry to this dewatering technique. The data shown in Table 8 provide some interesting information on the filtrability of this slurry.

The slurry solids concentration varied somewhat, but in general was in the 40 to 60 g/l range. For the media tested, POPR-859 produced a satisfactory filtrate quality, about 1.5 g/l of suspended solids for the fermented manure slurries.

Table 8. Filter Leaf Test Results¹

Filter Media	Iron ² g/l	Polyelec. ³ mg/l	Cake Solids %	Filtrate Sus. Solids - %
Manure				
POPR-859	7.0	10(A22)	14.6	0.15
PO-808	6.0	10(A22)	21.1	0.69
PO-808	2.1	0	29.2	1.01
PO-808	2.1	5(A23)	21.2	0.88
PO-808	2.1	10(A23)	18.0	0.44
NY-415	1.7	0	24.0	0.92
Corn Stover				
NY-415	0.0	0	17.4	0.75
NY-415	0.6	0	18.8	0.95
NY-415	11.7	0	22.1	0.94

¹Form time - 30 sec., drying time - 120 sec.

²Iron dosage as $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$

³Polyelectrolyte - Dow Purifloc A22 and A23

Unfortunately, this required a massive chemical dose and the resulting filter cake had a very high moisture level. The chemical flocculation of the fine particles results in a large quantity of water that is retained by the cake when removed by this medium. The same chemical treatment resulted in a cake of 21.1 percent moisture for the P0-808 medium. However, the filtrate suspended solids concentration was significantly higher. The cake solids content for the P0-808 medium was 29.2 percent with lower chemical addition, but again, the filtrate suspended solids concentration was 10 g/l.

The data show that higher cake solids can be obtained with limited chemical addition when using a coarse weave media. The data also show that the higher cake solids are produced at the expense of the solids capture. The filtrate suspended solids are significantly higher when a drier cake is produced. Attempts to use fine media such as the POPR-859 without chemical conditioning were a total failure. The medium clogged immediately and it was not possible to pull any liquid through the test leaf.

As a result of several tests, it became apparent that the most effective filter media for solids dewatering would be a coarse medium like NY-415. The effect of ferric chloride on this slurry filterability is shown in Figure 3. A cake solids of 20 percent was obtained without any chemical addition. A dosage of 1.7 g/l of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ (68 lbs per ton of dry solids) produced the maximum filter cake solids of 25 to 26 percent. The filtrate suspended solids were reduced from 12.5 g/l at 0 g/l iron to 8 g/l at a iron dosage of 1.7 g/l.

Figure 3. Cake and Filtrate Solids Obtained with Filter Leaf Test

The corn stover slurry filterability was similar to the manure slurry. Figure 3 shows the results of both slurries. The manure slurry produced higher cake solids for a given iron dosage. Because of the high concentration of alkalinity in the manure slurries (5 to 9 g/l as CaCO_3), the pH shift resulting from the iron addition was minimal. The final pH for the conditioned manure slurry was in the 6.5 to 7.0 range. However, the corn stover slurry alkalinity was low. A significant pH shift occurred with iron addition. These data are shown in Table 9. The impact of pH on filterability of the corn stover slurry is being investigated. Adjustment of pH on the manure slurry was not investigated because of the high buffer capacity of this slurry. Chemical requirements would be excessive.

Table 9. Effect of Iron Dosage on pH

Manure			Corn Stover		
Iron g/l	pH		Iron g/l	pH	
	Initial	Final		Initial	Final
1.7	8.1	7.4	1.0	7.6	6.7
2.1	8.3	7.4	4.7	7.7	4.2
7.0	7.8	6.4	6.7	7.7	2.8

Solids capture is one criterion for evaluation of filter performance. The data in Figure 4 shows the solids capture obtained with two media with various chemical dosage and form and drying times. In this figure, the open symbols are for 30 second form times which the closed symbols are for 15 second form times. The thicker cake produced with the longer form time resulted in higher solids capture due to the deeper media filtration effect of the thicker cake. Longer drying times

Figure 4. Solids Capture Using Filter Test Leaf Procedure

reduced the solids capture. This may have resulted from the extraction of more water and fine solids from the cake with the longer drying times and cake compression. High solids capture was possible but at a cost. Large chemical dosages and finer filter media yielded up to 97 percent solids capture.

The corn stover cake solids are about the same as the manure cake solids. The filtration rate is higher for corn but the solids capture is lower. This is because no chemicals were used to capture the fines on the relatively coarse NY-415 media. The corn curve for 30 second form time in Figure 4 shows poorer solids capture than the curve for 15 second form time. This may be result of cake compression after 15 seconds, pulling fines through the medium and reducing solids capture.

The expected vacuum filter performance based on the filter leaf test analysis is shown in Table 10. The finer medium, PO-808 provided a higher solids capture when a massive dosage of iron was added. Filtration rates were low and the cake moisture was low. The coarse medium NY-415 did not yield as high a solids capture, but the resulting cake was somewhat drier. The filtration rate was also better for NY-415 than for the finer medium.

Based on the results of this study, vacuum filtration does not appear to be a viable technique for processing these slurries. If dry cake and reasonable solids capture are the primary objectives, centrifugation will be more effective. If solids capture is not important, the large solids can be removed from the slurries with screens. Presses can then be used to produce a dry cake. A vacuum filter with a coarse medium may also be effective if cake solids in excess of 20 percent are not required.

Table 10. Expected Vacuum Filter Performance

Form Time Sec.	Dry Time Sec.	Cake Solids %	Filter Loading kg/m ² /hr	Solids Capture %
NY-415, FeCl ₃ - 1.7 mg/l Manure Slurry				
15	90	17.6	21.5	78.6
	105	17.0	17.6	77.4
	120	22.2	28.3	83.5
30	90	22.0	32.7	86.1
	105	21.9	28.8	90.2
	120	24.0	24.4	85.5
P0-808, FeCl ₃ - 7 g/l A 23-10 mg/l Manure Slurry				
15	90	19.5	24.4	83.0
	105	21.3	18.1	82.0
30	90	19.4	25.9	93.5
	105	21.9	22.5	97.0
	120	22.3	18.6	96.0
	135	21.0	15.6	85.0
NY-415 Corn Slurry				
15	90	14.6	39.7	36.0
	105	15.9	55.6	42.6
	120	16.0	39.3	38.0
	135	16.2	22.3	31.6
30	90	15.0	47.2	37.3
	105	16.5	24.5	32.2
	120	17.4	28.8	31.2
	135	20.2	27.7	24.4

6. Characteristics of the Fermenter Residue

The corn stover is deficient in nitrogen and phosphorus. These chemicals are added in order to maintain a balanced substrate for the microorganisms. Therefore, the quantity of these materials in the residue will depend upon the quantity added. One benefit of the fermentation process would be upgrading of the ammonia-nitrogen into protein nitrogen in the form of microbial protoplasm. Slurry analysis were conducted to determine the change in the nitrogen forms in this system. These data are shown in Table 11.

Table 11. Nitrogen Distribution in Slurries

Slurry	NH ₃ -N g/l	Organic N g/l	Total Solids g/l	Protein % T.S.
Feed 1	0.214	0.480	60.94	4.9
Reactor 1	0.170	0.428	36.55	7.4
Reactor 2	0.186	0.506	37.89	8.2
Feed 2	0.295	0.541	58.79	5.75
Reactor 3	0.286	0.498	38.80	8.0
Reactor 4	0.302	0.522	38.01	8.9

The quality of the solids is improved. The crude protein content (6.25 N) of the solids in the fermented slurry is significantly higher than in the feed slurry. However, a 9.0 percent protein content is not a very satisfactory feed protein. If the stover conversion efficiency could be significantly increased, the value of this residue as a feed material would be substantially greater.

7. Summary

At present, the corn stover does not appear to offer any promise as a source of methane. The excessively low conversion efficiency must be overcome if this substrate is to be of any use. Additional work will be undertaken with thermochemical pretreatment in an attempt to increase this yield.

8. Reference

Pfeffer, J. T., "Biological Conversion of Biomass to Methane - Beef Lot Manure Studies," U.S. Department of Energy Report No. C00-2917-9, Dept. of Civil Engineering, Urbana, IL, June 1978.