MASTER

ENERGY AND PROTEIN PRODUCTION
FROM PULP MILL WASTES

Progress Report
for Period September 15, 1977-December 15, 1977

M. F. Jurgensen and J. T. Patton

Michigan Technological University
Houghton, Michigan 49931

December 15, 1977

Prepared For
THE U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
UNDER CONTRACT E(11-1)-2983

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *ef*

NOTICE
This report was prepared as an account of work
sponsored by the United States Government. Neither the
United States nor the United States Department of
Energy, nor any of their employees, nor any of their
contractors, subcontractors, or their employees, makes
any warranty, express or implied, or assumes any legal
liability or responsibility for the accuracy, completeness
or usefulness of any information, apparatus, product or
process disclosed, or represents that its use would not
infringe privately owned rights.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately owned rights.

ABSTRACT

Effort during the past quarter was directed at two specific objectives. First, the conversion of the protein production experiments from batch to continuous operation and, second, the identification of growth stimulants to increase methane yield. Early in the project, yeast production ranging from 0.5 to 5.0 grams of dry yeast per liter had been obtained in batch cultures. Highest yields were consistently attained on SSL which had been ozonated for only 10 minutes. Continuous fermentation studies using three hour ozonated SSL confirmed the characteristic yields demonstrated in previous batch tests. Contamination, which occurred at residence times less than two days, appeared to decrease protein production rate and yield.

Vitamins and minerals, fatty acids, and low molecular weight alcohols were investigated as possible stimulants for methane production. Only the combination of alcohol plus vitamins and minerals seemed to be effective. Stimulated production failed to achieve the 25 ml per hour rate that had randomly been exceeded many times over the past six months. Additional culture studies are planned to examine the possibility that the mixed culture, now present in the anaerobic fermenters, has degenerated slowly over the past year.

BACKGROUND

The milestones identified at the initiation of the project were successfully accomplished on or ahead of schedule during the first

fifteen months of the project. Methane producing bacteria, obtained from various sources, were screened for the ability to grow on SSL. Several continuous fermenters were then inoculated with the most prolific gas producing organism and the research project achieved full operational status.

The effects of ozonation conditions on the modification of SSL were established. Experiments during the first year has indicated the optimum ozonation time to be less than 20 minutes and that the reaction should be conducted at pH's below 4. Work during the second project year is being directed at optimizing both ozonation and fermentation processes with respect to methane and yeast production. The proper sequencing of yeast and protein production is to be determined.

STAFFING

During this quarter the project was almost fully staffed with the exception being the absence of Dr. Juergensen from the campus until November 26, 1977. During the final two weeks of the project Dr. Jurgensen devoted full time to the project. Professional direction of the project was left to Dr. Patton whose appointment at New Mexico State University allowed him to spend 25% of this time actively directing the research work. He was able to spend only a total of seven days in Houghton in addition to data analysis and report preparation completed in New Mexico. Continuity was maintained by Ph.D. candidates Sushil, Dugar and research associate Craig Brennan

to 22 cc per hour. The addition of minerals or vitamins in addition to one of the alcohols on the average seemed to increase gas production only 50%. The addition of sodium lactate with or without additional vitamins and minerals also tended to stimulate production to the same extent. These observations must be considered only qualitative at this time. Additional experiments are designed to quantify the effect of different stimulants.

The lack of response in methane production when acetate or formate were added to the fermentation medium is surprising. The published literature suggest that acetic acid is presumably the preferred substrate for the production of methane. Experiments during this quarter fail to confirm the validity of this hypothesis. Not only does the addition of low molecular weight, fatty acids have no measureable effect on the fermentation but analysis of the fermentate supports the consistency of the data.

Analyses was performed on SSL before and after ozonation as well as the fermentate obtained at two different concentration levels. These data were presented in Table 1 with all values adjusted to a 100% SSL basis. It is significant that the fatty acids are not present in ozonated SSL at detectable quantities. However, after 3 hours of ozonation formate and acetate ions are present. After fermentation for periods varying from 3 to 5 days the concentration of acetate shows a consistent 6 fold increase over all experiments. In view of these data it is not surprising that the addition of acetate produced no appreciable increase in gas production.

TABLE I
EFFECT OF TREATMENT ON SSL COMPOSITION

Treatment	COD mg/l	BOD mg/l	Sulfur g/l	Low M.W. Fatty Acids, mg/l				
				Formic	Acetic	Propionic	Butyric	Oxalic
Unozonated SSL	93000 (10) ¹	9200 (7)	6.1	-	-	-	-	-
3 hr Ozonate	78000 (10)	11000 (10)	5.7	0.14	0.60	-	-	0.80
3 hr Ozonate Fermented 4 days	63000 (5)	6900 (3)	5.4	0.05	3.72	0.37	0.26	10.12
3 hr Ozonate Dilution 3:4 Fermented 4 days ²	63000 (10)	8500 (6)	5.1	0.09	3.96	0.30	0.35	50.06

¹Numbers in parentheses indicate number of values used to determine average

²A 75% concentration of SSL ozonated for 3 hrs. at a pH of 3.0, with values back calculated for 100% concentration.

on a day to day basis. It is anticipated that Dr. Jurgensen will have adequate time available during the last half to bring the overall staffing for the project up to the budgeted value for the total year.

RESULTS AND DISCUSSIONS

Methane Fermentation

Three anerobic fermenters were operated continuously during the entire quarter. Two of the fermenters were operated under identical condition on a substrate consisting of three hour ozonated SSL diluted 33% (3:1) with tap water. Fluctuations in methane production observed earlier in the project diminished considerably and near identical results were obtained from each reactor. These results will be utilized as the statistical base to accurately access future results. Total gas production averaged 8 cc per hour. Working volume for the fermenters was varied between 500 and 700 ml to establish residence times between 2 and 6 days. Although the gas rate was lower than desired the composition averaged above 80% which is exceptionally rich for methane fermentations.

A total of 34 steady state runs lasting approximately 5 days each were conducted on the two reactor pair. During these different experiments varying quantities of methol or ethyl alcohol, vitamins and minerals, and salts of low molecular weight organic acids were added in an attempt to stimulate methane production. The addition of alcohol, formate or acetate alone had no measureable effect on gas production. In one experiment the addition of a mixture of methol alcohol plus vitamins and minerals apparently stimulated gas production

The data also suggest the preferred process sequencing will be methane fermentation followed by yeast production. It is well established that yeast can effectively utilize acetate as a growth substrate. For this reason, research during the next quarter will examine the feasibility of growing yeast on ozonated SSL which has first been subjected to anaerobic digestion for the production of methane. It is anticipated that yeast production should show a significant increase unless contaminants produced in methane fermentation act to inhibit yeast growth or compete for the limited substrate under aerobic conditions.

SUMMARY AND CONCLUSIONS

Experiments during this quarter have demonstrated the reliability and advantages of utilizing a two reactor duplicate system for studying the effect of different growth stimulants and fermentation conditions. Gas production rates were below expectations and efforts are being made to identify the limiting factor responsible.

A variety of growth stimulants have been investigated; however, the results are only qualitative and fall short of the target production rates. The generation of acetate during anaerobic fermentation infers that a series of reactors consisting of methane production followed by aerobic yeast production may be the optimum sequencing for the process.

PLAN FOR THE FUTURE

During the next quarter additional efforts will be directed at quantifying the effect of growth stimulants on methane production. Additional factors will be investigated in hope of achieving the higher gas production rates which were obtained in the early phases of the program. The effect of ozonation times between 3 and 20 minutes will be determined to relate ozonation reaction time to the production of useable substrate. It is anticipated that media for all reactors will be prepared from SSL ozonated at shorter times in an effort to corroborate the optimistic results obtained in batch yeast experiments.