Microbial Pretreatment of Waste for Anaerobic Digestion

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Project Purpose

This project will demonstrate the technical feasibility of microbial pretreatment of lignocellulose for enhanced production of biogas when coupled with secondary anaerobic digestion.

Project Importance

Before anaerobic digestion of waste can reach its energy production potential, economically sound methods for pretreatments that allow increased digestion of waste materials must be developed. Many types of waste cannot be broken down sufficiently by anaerobic digestion alone. Despite the abundance of these types of waste material, anaerobic digestion of these potential energy sources remains inefficient because the anaerobic bacteria used in anaerobic digestion cannot readily consume the polymeric materials contained therein. These microorganisms are unable to break down long-chain molecules containing lignin. This is likely because plants have evolved defenses against bacterial attack. The main purpose of pretreatment of these waste materials is to alter the substrate composition in such a way that it is more suitable for anaerobic digestion. Therefore, pretreatment methods are attracting considerable attention for their potential ability to alter the structure and composition of the biomass and hence enhance (its) anaerobic digestion.

Overcoming this hurdle through successful feedstock pretreatment will unlock a vast potential supply of renewable energy feedstock materials. While physical, chemical, and enzymatic (biological) pretreatment methods have been thoroughly investigated, microbial conversion provides another possible solution and is the focus of the proposed project.

Project Profile Body

Many wastes such as harvest residues, paper and lumber mill waste, and short rotation woody crops are available on a broad scale. Municipal solid waste (MSW) contains a large percentage of construction, landscaping, and yard waste and is available on a localized basis. The energy potential of this material is significant, primarily due to its abundance and availability across most geography. Despite this, its value has not been sufficiently captured for two reasons. First, there is an inability to efficiently convert lignocellulose biomass to fuel. Second, prominent existing systems (like gasification and pyrolysis) require large quantities of waste to make economic sense. Therefore, transportation and logistics often overwhelm the financial benefits of the system. Anaerobic digestion offers a readily scalable and well-understood mechanism for utilizing waste as an energy precursor. Anaerobic digestion is not only feasible in large-scale industrial installations, but can also be applied on a small scale. This observation specifically provides opportunities for anaerobic digestion in developing countries and rural areas, where energy supply is limited or unavailable. On the other end of the spectrum, large-scale municipal waste treatment centers in the U.S. and Europe often employ this waste mitigation technology as well. Simply stated, anaerobic digestion systems may be constructed and operated where waste is available. More importantly, this may be accomplished at minimal cost relative to competing technologies. Therefore, if pretreatment facilitates enhanced lignocellulosic feedstock utility in anaerobic digestion processes, it represents a major advancement in renewable energy generation.

Various pretreatment methods for lignocellulosic biomass have been attempted. These pretreatments can be classified into physical (e.g., mechanical pulverization and limited pyrolysis), physicochemical (e.g., steam explosion and ammonia fiber explosion), chemical (e.g., acid hydrolysis, alkaline hydrolysis, high temperature organic solvent pretreatment and oxidative delignification), biological (e.g., lignin degradation by white- and soft-rot fungi), and electrical (PEF) methods and various combinations thereof.

While the benefits of efficient pretreatment are overwhelming, none of the previously described techniques has effectively surmounted the technical barriers or minimize the tradeoff between benefit and cost. Operational requirements, lack of process control, and expense ultimately diminish the value of currently available methods. Therefore, **it appears that the best option for conversion of the majority of carbon in these lignocellulosic feedstocks to a usable fuel is to employ microbial pretreatment of lignocellulosic anaerobic digestion feedstocks**. The finding of simultaneous lignin and carbohydrate solubilization (facilitated by Caldicellulosiruptor bescii) bodes well for industrial conversion by extremely thermophilic microbes of biomass that requires limited or, more importantly, no chemical pretreatment (Kateva, et al. 2013). **Past trials have yielded 85% lignin and cellulose solubilization rates when this bacterium is utilized. Therefore, this result will greatly improve down line methane production when pretreated feedstocks are introduced into secondary AD systems**. Direct AD processing of untreated waste lignocellulose degrades only ~30 % of cellulose fed into a high-rate AD system and virtually none of the lignin constituent.

A three-variable multivariate design will be used to structure the calorimetric experiments. Variables to be considered include 1) temperature (65, 75 and 85ºC initially), 2) pH (6, 7 and 8), and 3) substrate cellulose/lignin ratio (switch grass, corn stover, and populous sawdust). This program will require a total of 32 measurements, or 4 sets of measurements in the 8-channel calorimeter. The length of time for a set of measurements depends on the rate of reaction, but such measurements typically take from 3 to 7 days.

The proposed project is designed to 1) establish the technical feasibility of microbial pretreatment of lignocellulosic feedstocks in preparation for anaerobic digestion to produce biogas, and 2) optimize the entire process on a bench/prototype scale. The collected data will be used to determine the optimum circumstances for the pretreatment of feedstocks.

Anticipated Academic Outcome

I plan to prepare a manuscript presenting the results of this project, which will be submitted to the journal *Bioresource Technology.*

Qualifications

Dr. Hansen has 15 years experience working with the production of biofuels. He has published numerous papers on the subject and is considered a pioneer in Biocalorimetry.

I am currently a junior, and have taken general chemistry, as well as analytical chemistry and am currently taking organic chemistry. I have also been volunteering in Dr. Hansen's research lab for a semester.

Project Timetable

January-February 2014 – Collect Data
February-March 2014 – Analyze data
April 2014 – Write and submit manuscript to *Bioresource Technology*

Scholarly Sources

[Demonstrate you've conducted preliminary research by listing up to six sources. Use the appropriate citation style for your discipline]