DECENTRALIZED THERMOPHILIC BIOHYDROGEN: A MORE EFFICIENT AND COST-EFFECTIVE PROCESS

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Nonfood lignocellulosic biomass is an ideal substrate for biohydrogen production. By avoiding pretreatment steps (acid, alkali, or enzymatic), there is potential to make the process economical. Utilization of regional untreated lignocellulosic biomass by cellulolytic and fermentative thermophiles in a consolidated mode using a single reactor is one of the ways to achieve economical and sustainable biohydrogen production. Employing these potential microorganisms along with decentralized biohydrogen energy production will lead us towards regional and national independence having a positive influence on the bioenergy sector.

Keywords: Biohydrogen; Biomass; Lignocellulosics; Fermentation; Thermophiles; Decentralization

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INTRODUCTION

Hydrogen, a clean energy carrier with an energy density of 143 MJ/kg, is a promising alternative fuel for the future. Suitable biomass and appropriate microbial strains are two obligatory requirements for bio-based production of hydrogen, which then can be converted to electrical energy in fuel cells. Production of biohydrogen using nonfood lignocellulosic feedstock fits the true essence of a second-generation biofuel. Utilization of regional nonfood lignocellulosic feedstocks including agricultural and forestry residues should be considered as a priority, including initiatives to explore decentralized systems for hydrogen energy.

In the United States, high amounts of readily available biomass are located in the Midwestern region (Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin). For example, in South Dakota, lignocellulosic biomass in the form of prairie cord grass (PCG), corn stover (CS), and pinewood chips (PWC) are abundant, and can act as potential sources for biohydrogen production. Biohydrogen yields may vary, depending upon the nature and suitability of these regional biomass sources. However, an overall economic benefit can be realized in community-owned decentralized biofuel plants by avoiding transportation, including labor costs for carrying lignocellulosic biomass to experimental sites for bioprocessing to hydrogen. There are a few more concerns that should be addressed globally to make the biohydrogen production successful both technically and economically: i) The use of physico-chemical pretreatments (e.g. acid/alkali/elevated temperature) of lignocellulosic biomass generates secondary pollutants and inhibitory compounds for hydrogen-fermentative microbes, thus lowering rates of microbial hydrogen production. ii) High costs of cellulose and hemicellulose degrading enzymes used to hydrolyze pretreated biomass to fermentable sugars.

To address these concerns, there is an urgent need to develop a more efficient and cost-effective single-step process of biohydrogen production using lignocellulose-degrading and fermentative microbes. Recently much attention has been paid to the dark fermentative thermophilic bioprocessing (≥55°C) of lignocellulosic biomass, which can yield twice as much hydrogen as those under mesophilic conditions (30 to 40°C). In addition to increased hydrogen yield, the use of elevated temperatures offers several potential advantages, including improved hydrolysis of lignocellulosic substrates, higher mass transfer rates leading to better substrate solubility, lowered risk of potential contamination, and increased flexibility with respect to process design, thus improving the overall economics of the process. During dark fermentation, anaerobic microbes produce hydrogen while converting organic substrates into industrially important volatile fatty acids (acetate, butyrate, propionate) and alcohols (butanol, ethanol, propanol).

A viable option to lower the feedstock and lignocellulolytic commercial enzymes costs without compromising hydrogen yields is to screen hydrogen-producing thermophilic microorganisms capable of utilizing cellulose and hemicellulose directly from the untreated biomass at extreme pHs and temperatures. This eliminates the need for separate pretreatment steps (acid/alkali/enzymatic) and could provide a novel more efficient and cost effective consolidated process, as shown in Fig. 1. The hypothesis could be pursued that: "thermophilic cellulolytic and fermentative microbes can be used to produce hydrogen at greater rates from locally available abundant lignocellulosic materials in a single reactor". The scientific community working in the area of biohydrogen production should also develop a liaison with the industries that process plant biomass for production of different commercial products. Residual recalcitrant lignocellulosic biomass after industrial operations may be taken as a substrate for biohydrogen production. Conversion of lignocellulosic biomass using cellulolytic and fermentative thermophiles directly to hydrogen in a consolidated mode will not only generate energy but also solve the problems of agricultural, forestry, and industrial solid wastes management.

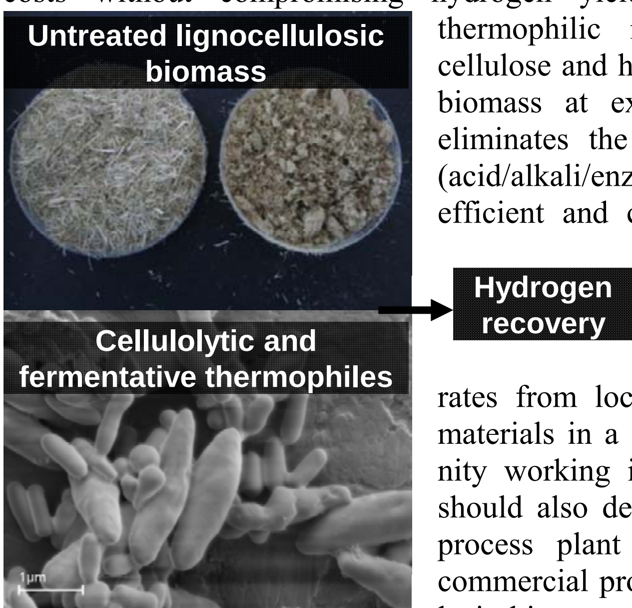

Figure 1. *A schematic diagram of the novel consolidated biohydrogen production process for hydrogen production utilizing untreated lignocellulosic biomass and cellulolytic and fermentative thermophiles.*

Acknowledgment

This work was supported by the South Dakota Governor's program and Board of Regents Competitive Research Grant. Sudhir Kumar is thankful to Jaypee University of Information Technology, Solan, HP, India for granting a sabbatical leave for doing research work at SDSMT, SD, USA.