The importance and challenges of agro-waste in second-generation biofuels production

Parveen Fatemeh Rupani[1, *], **Weilan Shao**[2]

1. School of Energy and Power Engineering, Jiangsu University, 212013, Zhenjiang, China, 2. Biofuels Institute, School of Environment and Safety Engineering, Jiangsu University, 212013, Zhenjiang, China

Received: 10/9/2020 Accepted: 18/11/2020 Published: 24/12/2020

Abstract

Innovative techniques produce the second generation of biofuels obtained from complex polysaccharides. Enzymatic hydrolysis of lignocellulosic biomass consists of cellulose and hemicellulose and convert them into sugars towards biofuels generation become the recent interests among the industries. However, its commercial utilization is still under investigation. The hydrolysis process requires multiple enzymes with different specifications such as cellulase and xylanase. Thermostable enzymes obtained from hyperthermophilic bacteria have been the core interest of scholars to utilize biomass degradation at the industrial level. Therefore, this work describes the second-generation substances towards biofuels production by considering hyperthermophile abilities and its enzymatic production challenges. Overall, the advancement in biofuels production will lead to achieving progressive green technology.

Keywords: Renewable energy; Biofuels; Agricultural wastes, Bacteria, Thermatoga, Green technology

1 Introduction

Fossil fuels, mainly coal, natural gas, and crude oil, play a leading role in the global energy system. In 2017, the total global fossil fuel consumption was 133,000 terawatt hour (TWh) (Smil, 2017). Furthermore, China's total fossil fuel consumption was recorded up to 22 megawatt-hours (MWh) in 2015 (Fig.1a). However, the consumption of these fuels is the major challenge for producing GHG and carbon dioxide (CO_2) in the atmosphere, and China accounts for 30% of the global CO_2 emission, as presented in Figure 2a (Boden, 2017). Recently, biofuels are an alternative that fossil fuels can effectively replace.

2 A different generation of biofuels

Biofuels are mainly categorized as first, second, third, and fourth-generation based on conversion sources. First-generation biofuels are produced from sugar/starch-based raw material. Starch-based biomass such as cereals and legumes are preferable compared to sugar-based materials, as they can produce higher hydrogen yield (Zabed et al., 2017). Lignocellulose materials are mainly considered second-generation biofuels. Recent attention has been given to microalgae sources to be utilized for biohydrogen production as third-generation biofuel sources.

Furthermore, finally, the 4th generation is based on utilizing vegetable oils and biodiesel. Among all, biofuels produced from ligno-based material and microalgae are the most promising substitutes. Although biofuels from plant materials are not coasted, practical and ongoing research is being conducted to overcome its barriers.

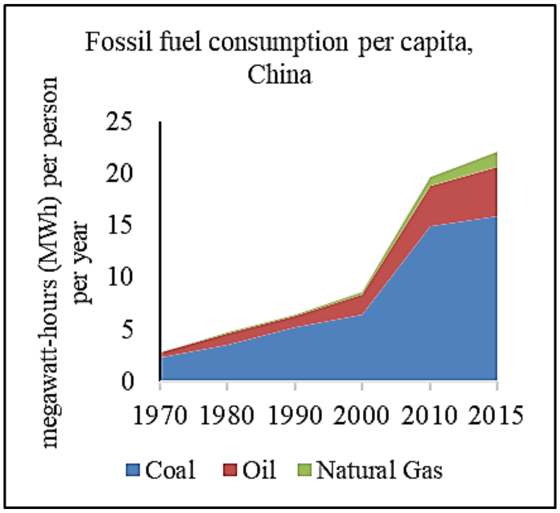

Figure 1: Fossil fuel consumption per capita in China, 2015
Source: (Smil, 2017)

Corresponding author: School of Energy and Power Engineering, Jiangsu University, 212013, Zhenjiang, China; parveen@ujs.edu.cn, https://doi.org/10.47277/JEEP/1(2)43

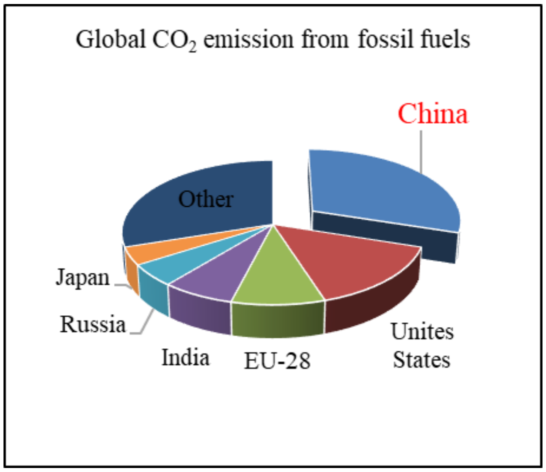

Figure 2: CO_2 emissions) from fossil fuels in different countries
Source**:** (Boden, 2017)

3 A different generation of biofuels

Different sources of biomass can effectively utilize to convert the waste into energy. Among those, lignocellulose biomass is the second-largest material having C6 and C5 sugar sources that make them a novel substrate for biohydrogen production (Simpson-Holley et al., 2007). Approximately 220 billion tons of lignocellulose biomass are generating annually in the world. This amount of waste equals 80 billion tons of crude oil, making it vital for proper management practices. Rezania et al. (2016) reported water hyacinth as a potential lignocellulose material that significantly produces biofuel production. Wheat straw is the second-largest ligno-biomass which produces biohydrogen with an approximate production of 3945 kg/ day (Pecha et al., 2013). Other lignocellulose biomass such as rice straw, corn Stover is also reported as a potential alternative source of biohydrogen production. As illustrated in Figure 3, the conversion of lignocellulose into biofuels is achieved through three different routes. However, utilization of such waste on large scale is still challenging. It is due to the challenging methods for the complex structure of lignin, its degradation, and pretreatment processes.

3.1 Lignocellulose pretreatments

There are different methods for treating lignocellulosic biomass, such as physical, chemical, and biological pretreatment methods reported to treat lignocellulosic biomass. Recently scholars are receiving more attention to the biological decomposition of biomass towards maximum H_2 production. The enzymatic treatment is mainly deployed after specific physical or chemical pretreatment. However, the attention is towards minimizing the pretreatment process by applying extremophilic microbes. There has been a growing interest in bacterial pretreatment of biomass using hyperthermophiles during anaerobic digestion. Extremophilic microbes have been reported from all three domains: archaea, bacteria, and eukarya included in the different phylum. Moreover, the application of bacteria shows a promising technique to eliminate the pretreatment process Zabed et al. (2019) reported that bacteria's growth and metabolic activity are faster than fungal species. Therefore, the application of hyperthermophilic microorganisms brings several advantages. In addition to the high metabolic activity, it results in less contamination rate due to their application in high temperatures.

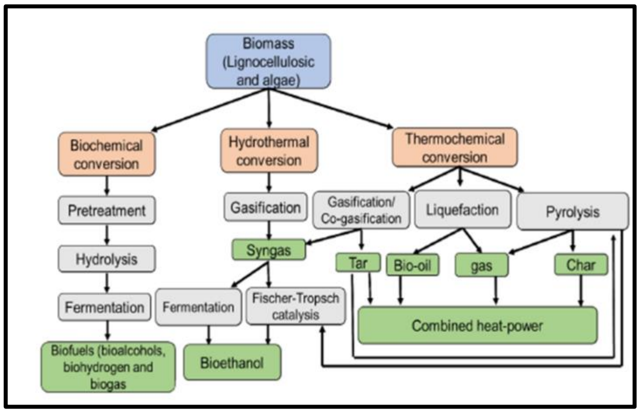

Figure 2: Biomass conversion and production of biofuels
Source: (Zabed et al., 2019)

4 A Hyperthermophiles

Hyperthermophiles are organisms that live in relatively high temperatures (> 80 0C). In a few decades, several hyperthermophiles were isolated from various sources such as thermal natural habitats or hot industrial environments. Most of the isolated hyperthermophiles belong to the order of archaea, while the Thermotogales family order is the only bacterial order discovered so far. The most exciting fact is that Thermotogales roots to extreme thermophiles, growing up to 95 ^{0}C. According to the phylogenetic tree of Thermotogales, *Thermotoga Maritima* (T.ma) and *Thermotoga naepolitana* (T.na) are two genetically close species with the ability to grow and degrade different biomass, including lignocellulose material.

4.1 Challenges towards hyperthermophilic enzymes

The major component of lignocellulose biomass is xylan which has a backbone of B-1,4- linked xylose. Therefore, digestion of such material needs a mixture of enzymes to penetrate the cell wall, such as xylanase. The first most important of xylanase over other enzymes are breaking down the xylan polymer into smaller monomers. However, the ability of the enzymes will be at its maximum level when applied at elevated temperatures such as high-temperature industries. For example, Wu et al. (2008) show that xylanase from *T.ma* was at its highest activity at extreme temperature (> 95 ^{0}C). Production of different enzymes such as cellulase and xylanase is through solid-state fermentation or submerged fermentation along with specific conditions affecting the production such as type of inoculum, pH, particle size, etc. Hyperthermophilic enzymes can be used as a catalyst source in industrial applications. However, the yield of the enzymes is often low and not at a satisfactory level for the industrial scale. At the same time, a high number of enzymes could produce on the laboratory scale.

5 Concluding Remark

Thermophilic microorganisms are well-known for producing catalyst enzymes such as cellulase, xylanase, and other valuable enzymes, benefiting from lignocellulose degradation. These thermostable enzymes serve the economic purposes to be used in industries towards biofuels production. The advantage of applying at high temperatures is, it will improve the enzyme's penetration into the lignocellulose cell wall. Thus, it will act as a physical factor to replace any pretreatment processes. However, the amount of enzyme produced by thermophilic microorganisms is lower than the one produced by mycophiles. Therefore, further research on genetic and bioinformatic analysis is required to better understand the structure and functional aspect of hyperthermophile and its enzymatic enhancement.

6 References

BODEN, T. A., MARLAND, G., AND ANDRES, R.J. 2017. National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory. *In:* ENERGY, U. S. D. O. (ed.).

PECHA, B., CHAMBERS, E., LEVENGOOD, C., BAIR, J., LIAW, S.-S., LEACHMAN, J., GARCIA-PEREZ, M. & HA, S. 2013. A novel concept for the conversion of wheat straw into hydrogen, heat, and power: a preliminary design for the conditions of Washington State University. Elsevier.

REZANIA, S., DIN, M. F. M., KAMARUDDIN, S. F., TAIB, S. M., SINGH, L., YONG, E. L. & DAHALAN, F. A. 2016. Evaluation of water hyacinth (Eichhornia crassipes) as a potential raw material source for briquette production. *Energy,* 111**,** 768-773.

SIMPSON-HOLLEY, M., HIGSON, A. & EVANS, G. 2007. Bring on the biorefinery. *Chemical engineer***,** 46-48.

SMILE, V. 2017. *Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy.* [Online]. Available: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html [Accessed].

WU, H., PEI, J., WU, G. & SHAO, W. 2008. Overexpression of GH10 endoxylanase XynB from Thermotoga Maritima in Escherichia coli by a novel vector with potential for industrial application. *Enzyme and Microbial Technology,* 42**,** 230-234.

ZABED, H., SAHU, J., SUELY, A., BOYCE, A. & FARUQ, G. 2017. Bioethanol production from renewable sources: Current perspectives and technological progress. *Renewable and Sustainable Energy Reviews,* 71**,** 475-501.

ZABED, H. M., AKTER, S., YUN, J., ZHANG, G., AWAD, F. N., QI, X. & SAHU, J. 2019. Recent advances in biological pretreatment of microalgae and lignocellulosic biomass for biofuel production. *Renewable and Sustainable Energy Reviews,* 105**,** 105-128.