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REVIEW ARTICLE

Optimizing biomass pathways to bioenergy and biochar application in electricity generation, biodiesel production, and biohydrogen production

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Abstract

The current energy crisis, depletion of fossil fuels, and global climate change have made it imperative to find alternative sources of energy that are both economically sustainable and environmentally friendly. Here we review various pathways for converting biomass into bioenergy and biochar and their applications in producing electricity, biodiesel, and biohydrogen. Biomass can be converted into biofuels using different methods, including biochemical and thermochemical conversion methods. Determining which approach is best relies on the type of biomass involved, the desired final product, and whether or not it is economically sustainable. Biochemical conversion methods are currently the most widely used for producing biofuels from biomass, accounting for approximately 80% of all biofuels produced worldwide. Ethanol and biodiesel are the most prevalent biofuels produced via biochemical conversion processes. Thermochemical conversion is less used than biochemical conversion, accounting for approximately 20% of biofuels produced worldwide. Bio-oil and syngas, commonly manufactured from wood chips, agricultural waste, and municipal solid waste, are the major biofuels produced by thermochemical conversion. Biofuels produced from biomass have the potential to displace up to 27% of the world's transportation fuel by 2050, which could result in a reduction in greenhouse gas emissions by up to 3.7 billion metric tons per year. Biochar from biomass can yield high biodiesel, ranging from 32.8% to 97.75%, and can also serve as an anode, cathode, and catalyst in microbial fuel cells with a maximum power density of 4346 mW/m^2. Biochar also plays a role in catalytic methane decomposition and dry methane reforming, with hydrogen conversion rates ranging from 13.4% to 95.7%. Biochar can also increase hydrogen yield by up to 220.3%.

Keywords Biomass · Bioenergy · Biochar · Electricity generation · Biodiesel · Biohydrogen

Introduction

Biomass is a renewable and sustainable energy source that has received considerable attention due to the need to reduce greenhouse gas emissions and reliance on fossil fuels (Osman et al. 2022a, 2023). Biomass conversion to bioenergy and products with added value, such as biochar, can occur via several pathways. Thermochemical conversion processes involve heating biomass at high temperatures without or in the presence of a limited amount of oxygen, producing bioenergy and biochar. Typically, techniques such as direct combustion, torrefaction, hydrothermal liquefaction, pyrolysis, and gasification are employed in this process (Osman et al. 2021). In contrast, biological conversion pathways utilize microorganisms to decompose biomass to produce biogas and biofuels, including biodiesel, ethanol, and bio-hydrogen (Farghali et al. 2022). This method typically employs fermentation and anaerobic digestion to break down the complex organic molecules present in biomass into simpler components that can be utilized as fuel, as shown in Fig. 1.

In this review, we examine various pathways of biomass conversion to bioenergy and biochar, as well as their applications in electricity production, biodiesel production, and biohydrogen production. Our main emphasis is optimizing biomass pathways and exploring the use of biochar in renewable energy. Furthermore, we evaluate biomass energy's environmental impact and sustainability and

Extended author information available on the last page of the article

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