Lignocellulosic Biomass as a Renewable Source

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Lignocellulosic biomass is the primary structural component of plant matter and is mostly inedible, generally referring to organic materials such as wood, grass, and agricultural crop residues. Biomass is a plentiful and carbon-neutral renewable energy source that may be used to create platform chemicals and fuels, especially considering that up to 75% of initial energy can be converted into biofuels.

Keywords: biomass ; lignocellulose ; photocatalyst photooxidation

1. Introduction

Biomass is a plentiful and carbon-neutral renewable energy source that may be used to create platform chemicals and fuels, especially considering that up to 75% of initial energy can be converted into biofuels. Lignocellulosic biomass comprises lignin, cellulose, and hemicellulose; lignin is almost 30% of the organic carbon in the biosphere. However, this lignin is regarded as waste material in several industries, for example, during paper TA and agricultural production, leaving significant amounts of biomass that contaminates the planet [1]. By 2035, bioenergy could provide 10% of the world's primary energy, according to the International Energy Agency (IEA), and biofuels may potentially replace up to 27% of global transportation fuel by 2050 [2]. According to Granone et al. [2] around 100 billion tons of biomass are produced worldwide each year, which makes it an available resource for obtaining biofuels [3] and chemical products with high added value [4][5][6].

Hydrocarbon compounds obtained from biomass have been used as intermediate molecules to produce chemical compounds and fuels. Biomass components (cellulose and lignin) have significant applications in the manufacture of various bio-based materials for solar energy, energy conversion, and storage devices [7][8][9][10][11]; it is especially true about lignin, and lignin derivates. However, lignocellulose is more challenging to transform than municipal and other industrial organic wastes. Biomass's advantage is not being edible, avoiding the depletion of food sources to obtain commodity chemicals or fuels [12]. Lignocellulose is very recalcitrant; thus, it is necessary to break down this component into little fractions to facilitate its conversion into valuable products, such as sugars, alcohols, phenols, furan derivatives, levulinic acid and γ-valerolactone, gluconic acid, 2,5-Furandicarboxylic acid, and more [13][14][15][16] or direct use as lignin nanoparticles that are useful for biomedical applications [17]. Some processes applied to lignocellulose transformation are gasification, pyrolysis [18], and hydrolysis, which all require high pressure and temperature fragmentation steps. Besides, the conversion and selectivity percentages reached are low, which a challenge to making this process profitable with a high yield in conversion and selectivity of degradation reactions [19]. The conservation of resources and high energy cost necessitate testing new processes requiring milder reaction conditions, such as biochemical and catalytic methods [20][21]. Heterogeneous photocatalysis emerges as a clean and very selective technology to obtain specific products from biomass. Titanium dioxide is the star catalyst used for biomass transformation because it is widely available, inexpensive, nontoxic, chemically, and physiologically inert, and stable when exposed to solar light. However, it has a band gap of 3.2 eV and can only absorb in the U.V. light spectrum, decreasing solar light energy conversion efficiency [22]. Titanium dioxide can produce several components under varying reaction conditions, making this catalyst a base for developing new modified catalysts [22][23]. To address the apparent disadvantages of titanium dioxide, several studies have investigated how to increase the Titanium oxide (TiO_2) performance during the conversion of biomass derivatives into additional products by doping it with different metals or macromolecules [24][25][26], and even using this catalyst as the base for developing new heterojunctions [27][28]. Studies have replaced TiO_2 by other catalysts, such as graphite carbon nitride ($g\text{-}C_3N_4$), to improve selectivity and conversion [29][30][31][32][33][34] and they are also interesting to review in order to have more options to transform biomass into useful products.

For these reasons, the photocatalytic process for the selective conversion of biomass derivatives is visualized as a sustainable and innovative technology because it is simple and low-cost. Moreover, the solar energy used in the process is abundant. It is one of the most economical alternative energy resources, which is transformed into chemical energy with the help of photocatalysts [35][36][37]. In this sense, photocatalysis of biomass reduces fossil fuel consumption, which minimizes environmental problems [38][39].

2. Biomass

Lignocellulosic biomass is the primary structural component of plant matter and is mostly inedible, generally referring to organic materials such as wood, grass, and agricultural crop residues [40][41]. The principal lignocellulosic biomass components are: lignin (20–30% *w*/*w*), cellulose (35–50% *w*/*w*) and hemicellulose (20–30% *w*/*w*) [40][41]. Regarding the structure of lignocellulosic biomass, the external cell of the biomass, which provides rigidity to the material, is rich in lignin [42][43]. It is a macromolecular polyaromatic with a high oxygen content [44][45]. On the other hand, cellulose is found inside lignin and forms hemicellulose-bound shells with a random structure. It is a stable crystalline biopolymer made of glycoside units. These units are insoluble in most solvents and difficult to hydrolyze [46]. Hemicellulose has an amorphous structure of pentose sugars such as xylose and arabinose, and hexose carbohydrates such as glucose, mannose, and galactose, so it is easier to hydrolyze than cellulose [10][46].

Although processing complex lignocellulosic materials is one of the main obstacles to commercial-scale biofuels and renewable chemicals, stimulating biofuel production has economic, environmental, and societal benefits. Different types of photocatalysts and reactors have been studied to decompose and process lignocellulosic biomass (or its components) [47][48].

Bio-oil is obtained from the lignocellulosic biomass conversion through thermal, catalytic, or both processes combined. The resulting bio-oil comprises oxygenated monomers such as cresols and guaiacols [6][49]. However, due to its high oxygen content, bio-oil is unstable and has a low energy content, and requires additional treatment to be used industrially [50]. Consequently, the transformation of platform molecules from lignocellulosic biomass (starting materials or building blocks to produce chemical products) has been identified as critical in converting biomass into fuels and chemical compounds [51]. The goal is to replace petrochemical compounds with renewable and sustainable compounds progressively. Moreover, the derivatization of compounds from biomass is crucial in recovering chemical products.

Some of the factors responsible for the attractiveness of biomass as a renewable source for conversion to chemical products are climate change and reduction in greenhouse gases [52], the need to search for renewable carbon sources as an alternative to fossil sources [52], the possibility to optimize the process of obtaining energy and chemical products [53], and finally, increasing public trust in the chemical business.

Selective oxidation of derivatives of lignocellulosic biomass is a promising process for obtaining chemical products in a sustainable way [54]. The biggest challenge is to make this process profitable with a high conversion yield and selectivity of degradation reactions. However, producing these chemicals requires high temperatures and high pressures, which results in increased energy consumption [55]. Furthermore, the conversion and selectivity percentages are low [43][44][56]. For this reason, the photocatalytic process for the selective conversion of biomass derivatives is viewed as a sustainable and innovative technology. Because it is simple and low-cost, solar energy used in the process is abundant and is one of the cheapest alternative energy resources; photocatalytically, this can be transformed into chemical energy.

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