Moreno, A.D.; Olsson, L. Pretreatment of Lignocellulosic Feedstocks. In: Extremophilic Enzymatic Processing of Lignocellulosic Feedstocks to Bioenergy, 2017, pp. 31-52. Sani, R.K.; Krishnaraj, R.N. (eds). Springer Nature, Switzerland. ISBN: 978-3-319-54683-4. https://doi.org/10.1007/978-3-319-54684-1_3

Pretreatment of Lignocellulosic Feedstocks

Antonio D. Moreno*, Lisbeth Olsson

Chalmers University of Technology, Department of Biology and Biological Engineering, Industrial Biotechnology, Gothenburg, Sweden.

*Correspondence to: Antonio D. Moreno, Chalmers University of Technology, Department of Biology and Biological Engineering, Industrial Biotechnology, SE-412 96, Gothenburg, Sweden.

E-mail address: davidmo@chalmers.se

Phone: +46 31-772 31 41

Abstract

With the aim of reducing greenhouse gas (GHG) emissions and with our dependence on non-renewable fossil fuels, lignocellulose has been proposed to be an alternative sugar-rich raw material for renewable biofuel production, especially for the transportation sector. Biorefineries can efficiently convert lignocellulosic biomass into fuels, value-added chemicals, and other forms of energy. When lignocellulose is transformed using biochemical routes, via sugar conversion platform the highly recalcitrant structure of lignocellulosic materials hampers the conversion process by limiting the accessibility of the chemical building blocks. It is therefore imperative to include a pretreatment step to reach high overall yields and productivity in subsequent hydrolysis and fermentation steps. The main purpose of pretreatment is to break down the structure of lignin and/or to solubilize hemicellulose in order to improve the accessibility of cellulose towards hydrolytic enzymes. The effects of pretreatment on the different lignocellulosic polymers depends on the type of pretreatment itself and the conditions used. This chapter outlines the most common physical, chemical, physicochemical, and biological pretreatment technologies that have been developed and optimized over last four decades for disruption and/or fractionation of lignocellulosic feedstocks. The mechanisms of action and the potential benefits and drawbacks of each pretreatment are listed and discussed. Furthermore, the pretreatment technologies are also analyzed from an economic and environmental point of view to evaluate their sustainability.

Keywords: Sugar biorefinery platform; Biomass fractionation; Biofuels.

1. Introduction

After the first oil crisis in the mid-late twentieth century, the need for a more sustainable and renewable energy system became clear. Today, 40 years later, a continuous increase in energy demand and the urgency in reducing carbon emissions are still good reasons for us to give up our dependence on non-renewable fossil resources. Consequently, the scientific community is in the process of helping to develop and implement novel technologies to establish the basis of a new bio-based economy that will bring relevant products for the energy, chemical, material, and food sectors. In this context, lignocellulose derived from plant biomass is a great source of renewable raw material in a bio-base economy because it is widely available, relatively inexpensive and do not compete with food production (FitzPatrick et al. 2010).

Lignocellulose is considered the most abundant renewable organic matter in nature, with an estimated annual production of more than 10^{10} MT worldwide (Sánchez and Cardona 2008). It includes agricultural waste, forest products, and energy crops, and its chemical composition varies depending on the raw material (Table 1). The main components of lignocellulosic biomass are cellulose, hemicellulose, and lignin. From a biochemical point of view, cellulose and hemicellulose consist of sugar units (glucose, xylose, mannose, arabinose, etc.), while lignin incorporates phenol-derived monomers (*p*-coumaryl, coniferyl, and sinapyl alcohol). Due to their different properties, each polymer has a specific role in the lignocellulosic material. Cellulose fibers interact to each other by hydrogen bonds, forming a compact crystal structure that confers rigidity and stability. Hemicellulose, on the other hand, acts as a link between cellulose and lignin, while lignin provides a recalcitrant matrix together with cellulose and hemicellulose and protects these two components from chemical and biological degradation (Brett and Waldron 1996). Furthermore, lignin is able to form ether- and ester-type covalent bonds with hemicellulose, forming lignin-carbohydrate complexes (LCCs) (Jørgensen et al. 2007). These intrinsic properties of lignocellulose give a three-dimensional structure that is difficult to disrupt. For optimal use of lignocellulosic feedstocks as an energy source, a pretreatment step to improve its digestibility is therefore essential.

1.1. Purpose of pretreatment

In a sugar biorefinery platform, lignocellulose is converted to several value-added compounds such as ethanol, organic acids, or lipids, by enzymatic hydrolysis and microbial/chemical catalysis processes (Fig. 1). Enzymatic hydrolysis of cellulose is carried out by cellulases, which major components are endo-1,4-β-D-glucanases (EC 3.2.1.4., attack cellulose regions with low crystallinity, creating new free chain ends), exo-1,4-β-D-glucanases (EC 3.2.1.91., degrade the cellulose molecule by releasing cellobiose units from the free chain ends), and 1,4-β-D-glucosidases (EC 3.2.1.21., hydrolyze cellobiose to produce glucose) (Jørgensen et al. 2007).