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Biodegradable ionic liquids in service of biomass upgrade

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Abstract

This work presents an up-to-date overview of the use of biodegradable ionic liquids in the conversion of biomass in the context of biorefineries. Special attention is given to works in which biodegradability potentiates advanced application of ionic liquids in terms of process intensification for deployment of technologies towards bioenergy carriers or bioderived value-added products.

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Climate changes are getting to a critical point when more actions are needed to reduce our carbon footprint. Furthermore, industries are having trouble achieving the rising population needs while decreasing their carbon footprint to meet new political and environmental demands [1]. For this reason, there has been a significant effort to develop new approaches to manufacture energy and materials from renewable resources. Among them, the most relevant are ones that would otherwise be wasted. This way it is possible to decrease society's dependence on petroleum-based industries and to contribute to a more circular economy [2]. These commandments have drawn increased attention to valorisation of biomass from agricultural, forest, and other industrial or municipal wastes, which allows avoiding its unnecessary disposal in landfills without its full potential having been achieved. Lignocellulosic biomass is the most abundant bio-renewable material on Earth [3] and is often not used to its full potential. Lignocellulosic biomass is mainly composed of 35−50% cellulose, 20−40% hemicellulose, and 5−30% lignin, depending on the biomass's source [4,5]. However, to keep ecological and economic benefits of all fractions of biomass, the breakdown of biomass matrix must be performed in a holistic manner without generating potentially toxic chemicals, which can limit the use of biomass-derived products in industries including energy, chemistry, food, or pharmaceutical.

The last years are marked with significant efforts towards developing more sustainable or greener approaches to biomass upgrading. These activities are most accomplished by the employment of green solvents. Among them, the most extensively studied are ionic liquids (ILs), especially when ILs are used for valorisation of biomass to value-added chemicals [6,7]. However, one of the main drawbacks in the use of ionic liquids is that some of them are not fully biodegradable and often with considerable toxicity against various organisms [8]. Especially, the most commonly used imidazolium-based ILs, despite being resistant to biodegradation, have the potential to bioaccumulate causing significant environmental problems. Due to this, there has been a growing demand in the development of new, non-toxic, biocompatible, and biodegradable ionic liquids (BILs). Therefore, this review aims to demonstrate the most relevant examples of the use of biodegradable ILs in the biomass processing reported between 2018 and 2021.

The most common BILs are those composed of naturally occurring biochemicals. Examples of such BILs are those with cholinium cation ([Ch]) and amino acid anions ([AA]) [9]. These kinds of ILs, also called bionic liquids, were demonstrated to be very efficient in, for example, biomass dissolution and particularly in the biomass delignification. [Ch][AA] ILs are non-toxic, biodegradable, renewable, and, being composed of naturally occurring biochemicals, can help cutting costs related to the downstream processing and facilitate the scale-up of the biomass pre-treatments. Bionic liquids are also more compatible with enzymes and microbes used for the further valorisation of the biomass. For these reasons, numerous studies have shown a great focus on [Ch][AA] ILs as the ones being promising for new applications as depicted in this work.

Other types of BILs are pyridinium-based ILs. Although they are known to be biodegradable, their building components are only rarely found in nature. The most common method of synthesis of pyridinium salts is the SN2 type reaction of pyridine with alkyl halides.