Breaking the Barriers of Lignocellulosic Ethanol Production using Ionic Liquid Technology

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Although the use of ionic liquids (ILs) has provided a potentially effective technical tool to improve the lignocellulosic ethanol production process, the technology still is facing great challenges with respect to its efficiency and economic viability. This editorial gives a systematical analysis of the potential and limitations of lignocellulosic ethanol production using IL technology. The use of ILs establishes a new platform for fractionation of lignocellulosic biomass. The IL pretreatment of lignocellulosic biomass can greatly increase its saccharification rate and the fermentable sugar yield. Use of ILs can also intensify the ethanol fermentation process and improve ethanol separation efficiency from its fermentation broth. However, many technical difficulties still exist in reducing the process costs and alleviating the environmental and ecological effects. More research and financial support are needed to overcome these difficulties.

Keywords: Breaking barriers; Ionic liquids; Lignocellulosic ethanol production

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Use of Ionic Liquids Provides a Promising Technical Tool for Improvement of Lignocellulosic Ethanol Production

Ever increasing energy demands and environmental concerns, together with diminishing fossil fuels reserves have contributed to making lignocellulosic ethanol production an attractive research area. Ionic liquids (ILs) are a group of new organic salts that exist as liquids at a relatively low temperature (<100 ℃). Interest in ILs has grown steadily in recent years because their non-detectable vapor pressure, non-flammability, high thermo-stability, unique solvent properties and close to infinite structural variation provide the possibility for improvement in the lignocellulosic ethanol production (Wang *et al.* 2011). Use of ILs has the potential to improve the lignocellulosic ethanol production at least from the following four aspects:

(1) Dissolution of lignocellulosic biomass or its subcomponents in ILs provides a new platform for effective fractionation of the lignocellulosic biomass and comprehensive utilization of its subcomponents, which can shorten the lignocellulosic ethanol production process and reduce its process cost (Cheng and Zhu 2009).
(2) The IL pretreatment of lignocellulosic biomass can increase the accessibility and reactivity of the carbohydrates in lignocellulosic biomass by deconstructing its three-dimensional structure and breaking down the semi-crystalline cellulose and hemicellulose without significant degradation of carbohydrates. Thus, it

accelerates the saccharification rate and increases the fermentable sugar yield (Han *et al.* 2009; Mora-Pale *et al.* 2011).

(3) Use of ILs as extractive solvents during the ethanol fermentation can effectively alleviate the product inhibition and intensify the ethanol fermentation process by coupling the ethanol fermentation and its separation together (Neves *et al.* 2011).

(4) Use of ILs as entrainers during ethanol separation from its fermentation broth by extractive distillation can reduce the number of plates and/or the recirculation ratio, leading to overall reduced separation costs and higher energy efficiency (Kokorin 2011).

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Although use of ILs provides plenty of possibilities to improve lignocellulosic ethanol production, there are still great challenges to overcome to make it an efficient and economically viable industrial process (Zhu *et al.* 2013a). The main technical challenges are summarized as follows:

(1) Reuse of ILs is extremely important in reducing its cost and alleviating its environmental and ecological effects for lignocellulosic ethanol production. Currently, there is a lack of suitable approaches to reuse ILs, especially when they are used to fractionate or pre-treat the lignocellulosic biomass (Zhu *et al.* 2013a).

(2) Large amounts of wastewater containing ILs are formed when they are used to fractionate or pre-treat the lignocellulosic biomass. Moreover, this wastewater cannot be treated by conventional methods. Therefore, how to treat this wastewater is still considered to be a headache (Zhu *et al.* 2013a).

(3) The residual ILs after their use in fractionation or pretreatment of lignocellulosic biomass have a negative effect on the subsequent enzymatic hydrolysis and ethanol fermentation process. Efforts to reduce the amount of residual ILs and their negative effects on the subsequent process still face many difficulties (Zhu *et al.* 2013b).

(4) The high cost of ILs definitely limits their application in lignocellulosic ethanol production. Reducing their cost and improving their properties is one of the most challenging tasks (Han *et al.* 2009; Mora-Pale *et al.* 2011; Wang *et al.* 2011).

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To address these challenges, more research and financial support are needed in the following aspects:

(1) In order to reuse the ILs used in fraction or pretreatment of lignocellulosic biomass, it is essential to establish a suitable regeneration technology that can effectively remove the impurities in ILs. Understanding the components of impurities in ILs and their mechanism of formation is the basis for establishment of a reasonable regeneration technology.

(2) Reducing the amount of wastewater containing ILs formed in fractionation or pretreatment of lignocellulosic biomass is the key to solve the wastewater treatment problem. This depends on optimization of the fractionation or pretreatment process after thoroughly understanding its process mechanism. Moreover, the development of new technology that uses this wastewater as a resource is equally important.

(3) In order to reduce the amounts of residual ILs and their negative effect on the subsequent enzymatic hydrolysis and ethanol fermentation process, optimization of the fraction or pretreatment process and development of tolerant enzyme and microbe are needed as two potentially effective routes to solve this problem.
(4) Based on modern synthetic chemistry, development of new low-cost ILs to meet the process demand is extremely important for lignocellulosic ethanol production using IL technology.

Although great progress has been made, more efforts from scientists and engineers are still needed to break the existing technical barriers in lignocellulosic ethanol production using IL technology. In the context of this joint effort, the authors believe that an efficient and economical-viable industrial lignocellulosic ethanol production process will be established in the near future.

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