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Optimization of microwave-assisted calcium chloride pretreatment of corn stover

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HIGHLIGHTS

- ▶ $CaCl_2$ was used as a microwave medium for corn stover pretreatment.
- ▶ Central composite design was employed to optimize the $CaCl_2$-pretreatment.
- ▶ The optimal conditions for corn stover glucose recovery were: 162.1 °C, 12 min.
- ▶ $CaCl_2$-pretreatment degraded up to 85.90% of the hemicellulose in corn stover.

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ABSTRACT

A 62.5% (w/w) $CaCl_2$ solution was used in the microwave pretreatment of corn stover. The central composite design (CCD) of response surface methodology (RSM) was employed to design and optimize the $CaCl_2$-assisted microwave pretreatment ($CaCl_2$-pretreatment). Temperature and time were the main factors affecting the enzymatic digestibility of corn stover. After $CaCl_2$-pretreatment, hemicellulose degradation reached 85.90%, the specific surface area (SSA) increased by 168.93%, cellulose crystallinity index (CrI) decreased by 13.91% compared to untreated corn stover. The optimal conditions for glucose production with the $CaCl_2$-pretreatment obtained by CCD were, 162.1 °C, 12 min and solid-to-liquid ratio 10% (w/v). Under these conditions, the enzymatic hydrolysis ratio of cellulose was 90.66% and glucose recovery was 65.47%. This novel process achieved the temperature of about 160 °C necessary for lignocellulose pretreatment under atmospheric pressure using the cheap calcium chloride as the heating medium.

1. Introduction

By biorefining, lignocellulose can be converted into fuels, useful materials, and chemicals (Liu et al., 2011). Since lignocellulosic materials have a complex multi-component three-dimensional structure, utilization of cellulose, hemicellulose and lignin requires pretreatment such as steam explosion (Li and Chen, 2008), and hydrothermal (Xu et al., 2010) and microwave pretreatment (Xu et al., 2011). These pretreatment methods involve cooking the lignocellulosic materials in a pressure vessel at about 200 °C (Li and Chen, 2008; Xu et al., 2010). The use of pressure vessels causes high equipment costs and makes a continuous process challenging because it is difficult to transfer solid materials into a pressure vessel and discharge them without backmixing (Heitz et al., 1991). In contrast, with pretreatment at atmospheric pressure, it is easy to achieve continuous processing, which will likely increase the efficiency of the pretreatment process (Intanakul et al., 2003).

Microwave pretreatment has been proven as an effective pretreatment method. Microwave irradiation enhanced the enzymatic susceptibility of rice straw soaked in water in a tightly closed or sealed glass vessel under a certain amount of pressure (Azuma et al., 1984; Ooshima et al., 1984). A microwave pretreatment under atmospheric pressure was developed by Intanakul et al. (2003) who immersed ground rice straw or sugar cane bagasse in glycerine with the addition of a small amount of water. A temperature of about 200 °C could be reached in this medium without high pressure built up.

The present study attempted to pretreat corn stover using microwave as heat source and calcium chloride ($CaCl_2$) solution as the medium to enhance its enzymatic hydrolysis performance. Using of $CaCl_2$ solution for microwave heat medium can achieve temperatures above 100 °C required for pretreatment under atmospheric pressure without the requirement for a pressure vessel. Calcium chloride is cheap, easily obtained, and its price is only a fifth of that of glycerine. This can reduce the equipment investment and variable costs on the pretreatment operation unit and make a continuous pretreatment process.

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